BC
B625 H93
D MoP726
1983
c.2

MURPHY CREEK PROJECT

PRELIMINARY DESIGN

GROUNDWATER STUDIES

Prepared for: Hydroelectric Generation Projects Division
B.C. Hydro and Power Authority

Purchase Orders: 053 392
243 491

Prepared by: Pacific Hydrology Consultants Ltd.
January 1983

Canadian Cataloguing in Publication Data

Main entry under title:
Murphy Creek Project preliminary design groundwater studies

Cover title: Columbia River-Murphy Creek Project : preliminary design groundwater studies.
Bibliography: p.
ISBN 0-7719-9325-0

1. Water, Underground - British Columbia - Central Kootenay. 2. Water, Underground - British Columbia - Kootenay Boundary. 3. Murphy Creek Project. I. B.C. Hydro. Hydroelectric Generation Projects Division. II. Pacific Hydrology Consultants Ltd. III. Title: Columbia River-Murphy Creek Project : preliminary design groundwater studies.

GB1030.B7M87 1983 551.49'09711'44 C83-092282-2

MURPHY CREEK PROJECT

PRELIMINARY DESIGN

GROUNDWATER STUDIES

Section	Subject	Page
1.0	INTRODUCTION AND TERMS OF REFERENCE	
	1.1 Purpose and Scope	1 - 1
	1.2 Authority and Terms of Reference	1 - 1
	1.3 Acknowledgements	1 - 3
2.0	GEOLOGY AND GROUNDWATER HYDROLOGY	
	2.1 Regional Geology of the Columbia River Valley	2 - 1
	2.2 Groundwater Hydrology in the Columbia River Valley	2 - 4
3.0	AQUIFERS AND GROUNDWATER USE IN THE COLUMBIA RIVER VALLEY AND IMPACTS OF DAM CONSTRUCTION	
	3.1 General	3 - 1
	3.2 Oasis - Rivervale Area	3 - 4
	3.3 Trail Municipal Wells	3 - 8
	3.4 Trail to Canada-United States Boundary	3 - 10
4.0	IMPACTS OF MAINTAINING A RESERVOIR LEVEL OF 424 m ON HIGH WATER TABLE AREAS	
	4.1 Castlegar Area	
	4.1.1 Geology, Topography and Groundwater Hydrology	4 - 1
	4.1.2 Character of the Groundwater Flow System under North Castlegar	4 - 3
	4.1.3 Impacts of 424 m Reservoir Elevation	4 - 5
	4.2 Other Areas	
	4.2.1 East Raspberry Area	4 - 7
	4.2.2 Benches Along the Columbia River	4 - 9

Section	Subject	Page
5.0	IMPACTS OF MAINTAINING A RESERVOIR LEVEL OF 424 m ON GROUNDWATER QUALITY	
	5.1 Selkirk College Aquifer	5 - 1
	5.2 Septic Tank - Tile Drain Facilities and Landfills	5 - 3
	5.3 Dam Construction	5 - 3
6.0	SUMMARY AND CONCLUSIONS	6 - 1
7.0	RECOMMENDATIONS	7 - 1
8.0	SELECTED REFERENCES	8 - 1

APPENDICES

APPENDIX A	WATER WELL INVENTORY
APPENDIX B	PUMPING TESTS AT OASIS
APPENDIX C	WATER QUALITY INFORMATION

FIGURES

Figure 1-1	Area Location Map
Figure 1-2	Well Inventory Index Map
Figure 2-1	Keenleyside Dam-Robson Area
Figure 2-2	Robson Area
Figure 2-3	East Raspberry Area
Figure 2-4	Brilliant-Ootischenia Area
Figure 2-5	Kinnaird-Ootischenia Area
Figure 2-6	Kinnaird-Ootischenia Area
Figure 2-7	Blueberry Creek Area

FIGURES (cont'd)

Figure 2-8		Poupore-Genelle Area
Figure 2-9		Sullivan Creek Area
Figure 2-10		Birchbank-Rivervale Area
Figure 2-11		Oasis Area
Figure 2-12		Trail-Montrose Area
Figure 3-1		Schematic Hydrogeological Cross-Section A-A'
Figure 3-2	A.	Schematic Hydrogeological Cross-Section B-B'
	B.	Schematic Hydrogeological Cross-Section C-C'
Figure 4-1		Areas in Castlegar which could be affected by High Water Tables
Figure 4-2		Areas on Pass Creek Delta which could be affected by High Water Tables

TABLES

Table A-1	Well Inventory - Keenleyside Dam-Robson Area
Table A-2	Well Inventory - Robson Area
Table A-3	Well Inventory - East Raspberry Area
Table A-4	Well Inventory - Brilliant-Ootischenia Area
Table A-5	Well Inventory - Kinnaird-Ootischenia Area
Table A-6	Well Inventory - Ootischenia Area
Table A-7	Well Inventory - Blueberry Creek Area
Table A-8	Well Inventory - Poupore-Genelle Area
Table A-9	Well Inventory - Sullivan Creek Area
Table A-10	Well Inventory - Birchbank-Rivervale Area
Table A-11	Well Inventory - Oasis Area
Table A-12	Well Inventory - Trail-Montrose Area
Table B-1	Results of Pumping Tests at Oasis
Table C-1	Groundwater Quality - Trail Wells
Table C-2	Quality of Columbia River Water
Table C-3	Groundwater Quality at Oasis

1.0 INTRODUCTION AND TERMS OF REFERENCE

1.1 PURPOSE AND SCOPE

The purposes of this report are to:

1. review the occurrence of groundwater, its flow systems and use along the Columbia River between Castlegar and the Canada-United States Boundary (Figure 1-1).

2. as a result of 1. assess the impacts of the construction of the Murphy Creek Dam and the formation of a reservoir at elevation 424 m on groundwater and wells along the Columbia River.

Particular emphasis in this report is given to the geology and to the character of the local and regional groundwater flow systems through which water moves underground from recharge areas in the uplands to discharge areas in the major valleys.

1.2 AUTHORITY AND TERMS OF REFERENCE

In response to an invitation from B.C. Hydro and Power Authority, Pacific Hydrology Consultants Ltd. submitted a letter of proposal dated November 12, 1980 in reference to the possible effects of the proposed Murphy Creek Dam on groundwater and wells along the Columbia River.

The letter of proposal was accepted and Purchase Order No. 053 392 of December 3, 1980 was issued to Pacific Hydrology to write a brief report on groundwater geology and hydrology. Such a report, Effects of Proposed Murphy Creek Dam on Groundwater and Wells along the

Columbia River, was prepared and submitted in January, 1981. Further groundwater studies, as part of Preliminary Design of the Murphy Creek Dam, were authorized by Purchase Order No. 243 491. Portions of the earlier report have been used as part of this report with only minor revisions.

The Terms of Reference for the Preliminary Design Groundwater Studies are as follows:

1. The Consultant shall compile, from well logs and maps, all existing information about wells in the area. The Consultant shall also communicate with water-well contractors in the area, obtain any additional information about the wells, and compile this information. In the Oasis-Rivervale area the Consultant should obtain copies of well-users logs where these are available. Assessments of these logs should be made and the logs kept on file.

2. The Consultant shall carry out an inventory of all water wells in Oasis and Rivervale and any others which could be affected by project construction activities and the formation of a reservoir at elevation 424 m. Wells which would be lost to flooding should be identified, but not included in the inventory.

3. The Consultant shall designate wells in which water levels should be observed for a period before and after construction of the project. If required, the Consultant shall make arrangements for these observations. The Consultant should assess the annual variability of well water levels in the Oasis-Rivervale area and how these are related to river level fluctuations.

4. The Consultant shall designate wells for which pump tests should be carried out, and should then make arrangements for these tests. All wells in Oasis and Rivervale should be tested. If a well owner refuses to allow a pump test, this refusal should be documented. If an owner of a closed well wishes to have a pump test done, then the Consultant should engage a local contractor to open and close the well.

5. The Consultant shall designate two, or more, wells for which complete water quality tests should be carried out. In addition, field analyses of pH, conductivity and temperature will be made whenever possible. All accessible wells in Oasis and Rivervale should be tested.

6. The Consultant shall study municipal wells in Trail located adjacent to the River and advise on any impact on flow rates or water quality from construction activities. The Consultant should locate all wells in the reach between Trail and the U.S. border which are located within the zone of influence of the Columbia River. An assessment of the impact of project construction on these wells should be made, with special emphasis on wells in Montrose and other communities on the left bank of the River.

7. The Consultant shall study the existing regional groundwater in the Columbia River Valley between the project site and the Hugh Keenleyside and Brilliant Dams. The Consultant shall study the impact of construction activities and the formation of a reservoir at EL 424 m on the regional groundwater. The Consultant shall prepare groundwater contours, where possible, in built-up areas to help identify areas of possible basement flooding. The Consultant shall avail himself of information obtained by Thurber Consultants during their 1981 drilling program and subsequent water level measurements, as well as other water level data that may be available.

8. The Consultant shall prepare a report based on the studies outlined above, including the results of all well testing and analysis of possible basement flooding.

9. The Consultant should recommend a monitoring program during and after construction for all wells investigated in this study.

1.3 ACKNOWLEDGEMENTS

Preparation of this report would not have been possible without the assistance of B.C. Hydro personnel, particularly Mr. N. Nielsen, P. Eng. and Mr. K. Ketchum, P. Eng. Topographic mapping in the study area was supplied by B.C. Hydro.

The co-operation of residents in the study area facilitated the well inventory: their help is gratefully acknowledged. In addition, the assistance of the Groundwater Hydrology Section of the Ministry of Environment in supplying water well location maps and copies of well logs is acknowledged with our appreciation. The information

provided by Mr. Wiesner, City Manager at Trail, was helpful in our assessment of the situation at Trail and his assistance is acknowledged.

2.0 GEOLOGY AND GROUNDWATER HYDROLOGY

In an assessment of the regional groundwater resources, and of the local and regional impacts on groundwater from construction of a major structure such as the Murphy Creek Dam, an understanding of the regional and local geology is important. This report therefore gives considerable emphasis to the geology and the character of groundwater flow systems. This section of the report describes the regional geology and groundwater hydrology of the Columbia River Valley.

2.1 REGIONAL GEOLOGY OF THE COLUMBIA RIVER VALLEY

The Columbia River Valley was shaped by river erosion and also by intense repeated glaciation over a period of about 3 million years. Each advance of glacial ice tended to clear the valley of sediment from previous glacial episodes so that conditions today are largely the result of the last series of glacial events which ended about 10,000 years ago.

Ice advances in valleys are largely erosional events, but during ice melting and retreat very large volumes of sediments may be deposited. In the Columbia River Valley, as in most other major valleys in the interior of British Columbia, drainage was blocked temporarily during the most recent glacial episode. This resulted in the formation of enormous lakes in which thick, silty, sandy lake beds were deposited. There is evidence in the Okanagan Valley and in the Kootenay Valley that the blocking of drainage was associated with rapid ice advances from ice-covered uplands into the major valleys by way of tributary valleys. These ice tongues blocked drainage temporarily, perhaps for about 100 years, before the dams of ice and glacial debris collapsed and released the lake

water to produce tremendous floods. There is some evidence for such a sequence of events in the Columbia River Valley.

Thus, the sequence of events from the beginning of the last regional glaciation in the subject area has been more or less as follows:

1. Advance of regional ice from the north, covering all but the highest mountain peaks.

2. A long period of melting during which the major valleys became partially or entirely free of ice; ice remained in the uplands. Outwash sediments from meltwater were largely carried southward in major river systems.

3. Rapid cooling with an increase in precipitation, bringing about rapid advance of valley glaciers from ice-covered uplands into major valleys such as the Columbia. Several periods of rapid advance and retreat may have been involved.

4. Blocking of major drainage by ice and glacial debris from tributary valleys. This brought about the formation of huge lakes up to 200 m deep in the major valleys. These lakes trapped large volumes of sediment from meltwater as lake beds, raised deltas, outwash plains, etc.

5. Sudden drainage of the lakes, resulting in brief huge floods. The rapid drainage partially cleared the major valleys of the sediments that had been deposited during the lake phase.

6. Continued wasting away of ice in the uplands with downcutting of raised deltas at creek mouths and redeposition of granular material, largely as fans and floodplain deposits, along the major rivers.

7. From (6) to the present, perhaps 9000 years, continuous erosion and deposition with rates of erosion and deposition close to those of the present time.

In the Columbia Valley Between Castlegar and the U.S. Boundary there are deposits of sediment and erosional features which had their origin in the events outlined above.

The evidence of regional glaciation in the Columbia Valley is widespread, especially in the uplands where an intermittent blanket of bouldery grey till is evidence of glacial deposition and glacial striae are evidence of intense erosion. The evidence for the later local ice advances in tributary valleys is less obvious and therefore more controversial.

Along the Columbia between Castlegar and Waneta, there are "benches" on both sides of the River. They are the remnants of a continuous fill of sediment, most of which was removed in post-glacial floods. Logs of water wells and a few foundation testholes indicate that this fill is composed of a jumbled mixture of sediments ranging in size from boulders to clay, the dominant portion being sand. The contorted and "mixed-up" nature of the material may be seen in surface exposures, in road cuts, in gravel pits and in natural exposures along tributary creeks. This complex of materials may be termed ice contact deposits because they were apparently deposited in contact with melting ice. This suggests that ice from tributary valleys may have partly occupied the Columbia Valley while it was blocked further downstream. The top of the benches in the Trail-Castlegar stretch of the Columbia River Valley is about 580 m elevation. The top surface is often uneven, probably because of the nature of the underlying material. This indicates that the Columbia Valley has been cut down about 150 m since the deposition of ice contact sediments in the Valley.

The situation at Castlegar is different. The low ridge in the north part of Castlegar and across the Columbia River from Castlegar, and on which Selkirk College is located, is probably a moraine ridge. The general alignment of the ridge and other topographic features indicate that the ridge is a terminal moraine deposited by ice which came down the Kootenay River Valley, or perhaps down the Pass Creek Valley. Raised deltas and by-pass channels at the Castlegar Golf Course and in the Krestova-Pass Creek Valley indicate that the top of the ice

at Castlegar was at about 500 m elevation. The ridge at Castlegar may be called the Castlegar moraine.

Drilling in the old village of Castlegar and near Selkirk College shows that the moraine is made up of ice contact deposits which include huge boulders and very clean gravel. Gravelly parts of the moraine are an excellent aquifer; other parts are hardly permeable enough to yield any water to wells. These ice contact sediments differ from those forming the "benches" along the Columbia River in that they contain a much larger proportion of coarse gravel and boulders.

Upstream from Castlegar along the Kootenay River and also downstream along the Columbia River toward Trail, there are gravel deposits on the river benches and also on lower terraces; these are probably of torrential origin. These torrential features have not been studied along the Columbia so their extent is unknown. They are widespread and prominent along the Kootenay River between Shoreacres and Thrums and downstream from Trail. Torrential features developed during brief periods of extremely high river flow when collapse of glacial dams released huge volumes of impounded water from glacial lakes.

2.2 GROUNDWATER HYDROLOGY IN THE COLUMBIA RIVER VALLEY

Along the Columbia River practically all groundwater originates as precipitation. With the exception of a few unusual aquifers which will be discussed later, groundwater along the Columbia River does not come from the River but is moving through aquifers toward the River from uplands along the river valley. Schematic hydrogeological cross-sections in three areas are included with this report as Figures 3-1 and 3-2 to demonstrate groundwater flow patterns in the Castlegar, Oasis and Trail areas. The locations of the cross-sections are shown on Figure 1-2.

The concept of the groundwater flow system is not particularly new but recognition of the significance of very large scale flow systems is quite recent. Flow takes place through relatively impermeable materials like silt, clay and rock as well as permeable sand and gravel. Flow through the types of rocks found in the Castlegar-Trail area occurs almost entirely in fractures, and the rocks are therefore said to have fracture permeability. The velocity of flow in materials of low permeability is extremely low but, because of the huge volume of material involved, the quantities may be significant.

Most recharge in the subject area is intermittent because of the local climate. It also has quite an uneven areal distribution, again because of local climatic factors and because of the role of vegetation. Because precipitation is much greater in the uplands than in the valley along the Columbia River, more water is available for recharge in the uplands. During the growing season much of the precipitation is taken up by plants and almost all precipitation is returned to the atmosphere by processes of evaporation and transpiration. During the summer months a soil moisture deficit develops because of evapo-transpiration. After the growing season has been brought to a close by frost, autumn precipitation is held in the soil until the soil moisture deficit has been satisfied. Winter recharge in the uplands is very low because the precipitation is held as snow and ice. Therefore, significant groundwater recharge takes place only during the period of run-off in early spring.

In spite of the fact that recharge is seasonal, groundwater flow is quite steady and is certainly continuous except in small local flow systems. The low average permeability combined with long path of flow smooths out seasonal variations in flow.

The chemical quality of water changes from unmineralized rain and snow as the water moves through granular materials

and through fractures in rock. Water moving through short, relatively fast-moving flow systems picks up little mineralization because of short contact time and the relatively small surface area of coarse-grained permeable materials. Water moving slowly through rock fractures far below the ground surface may be in contact with rock for many years under high temperature conditions, thus becoming quite highly mineralized. The character of the mineralization in groundwater also depends to some extent on the minerals present in the sediments or rock through which the groundwater moves.

3.0 AQUIFERS AND GROUNDWATER USE IN THE COLUMBIA RIVER VALLEY AND IMPACTS OF DAM CONSTRUCTION

3.1 GENERAL

Tables A-1 to A-12 in Appendix A summarize the results of a well inventory and review of driller's logs of water wells in the study area. The locations of all wells in the Tables are shown on Figures 2-1 to 2-12. The area of the well inventory extended from the Keenleyside Dam south to the Canada-United States Boundary with special emphasis on the area from Oasis northward (Figure 1-2).

In the area under discussion there are four main types of aquifers supplying water to wells:

1. Fractured rock.
2. Ice contact sediments of the benches along the Columbia River.
3. Ice contact sediments of the Castlegar Moraine.
4. Modern fan deposits at the mouths of tributary creeks.

Wells drilled into fractured rocks have low capacity but are often used for domestic supply. These wells intercept water which is moving through the fractures toward discharge zones. There are a number of these wells in the Oasis area.

Wells in the ice contact sediments of the benches along the Columbia River may have medium capacities if they are properly constructed and have encountered permeable parts of the deposits. The water which the wells receive is water which is moving toward the River through groundwater flow systems recharged in the uplands. It is conceivable that

pumping at high rates for a very long period from a well located very close to the River might induce flow from the River to the wells. Usually this is not the case. The wells which formerly supplied water to North Castlegar and South Castlegar (Kinnaird) are examples of wells which obtain water from ice contact sediments: the North Castlegar wells are constructed in coarse sand and gravel while the South wells obtain water from materials which are somewhat finer. It is worth noting that the water quality from the two areas is different. An existing well in each of these areas has been retained by the City of Castlegar for standby; all other wells have been abandoned.

The Castlegar moraine, particularly the portion on the east side of the Columbia River at Selkirk College, is a special case. This important aquifer has very permeable portions which are capable of supplying water to very high capacity wells. They hydrology of the portion of the aquifer under the old Village of Castlegar (North Castlegar) may be much like that of the benches mentioned above. Chemical analyses of water indicate that the aquifer contains water moving toward the River in a large groundwater flow system. The portion under the point of land at Selkirk College is surrounded by the Kootenay and Columbia Rivers on three sides. The aquifer probably contains water moving from the Kootenay River to the Columbia which is at a slightly lower elevation. The chemical quality of groundwater in North Castlegar is like that in the benches along the Columbia River while that at Selkirk College is much less mineralized and is similar to that in the Kootenay River. Therefore, wells on the point probably receive water mostly from the Kootenay River. Figure 3-1 is a schematic hydrogeological cross-section to illustrate the situation at Castlegar.

Creeks tributary to the Columbia River have cut down through the benches along the River and have deposited fans. The fans are made up of gravel with variable amounts of sand and silt. Most fans are highly stratified and consist of alternating layers of clean gravel

and silty gravel. Water moves down from the creeks into the fans; this groundwater then moves mostly along the cleaner layers toward the Columbia River where it is discharged below river level. Thus, subsurface flow is toward the River; wells in fans do not receive water from the Columbia River. Wells constructed in fans may have moderate capacity depending largely on their design and construction. A well constructed at Genelle in the fan materials of China Creek supplies as much as 16 l/sec to the Genelle-China Creek system.

The level of water in the Columbia River affects the elevation of the water table in the aquifers adjacent to the River but has little influence on groundwater flow. In the case of the Castlegar moraine, because of high permeability and hydraulic connection with the River, the static level in wells will rise and fall almost exactly with the River. Because of the flow of groundwater through the sediments bordering the River, the water table slopes toward the River by an amount which is controlled by the rate of groundwater flow and the permeability of the aquifer. Under these conditions, changes in the level of the Columbia River will affect the elevation of the water table at any particular location by an amount which depends on the slope of the water table and the distance from the River. The path and the rate of groundwater flow will not be changed significantly. The same is true of the fan aquifers. River level changes under these conditions will have no effect on the quality of groundwater in the aquifers along the River because the water is not from the River. The possible exception is the aquifer at Selkirk College where water in the aquifer probably originates in the Kootenay River.

An inventory of water wells in Oasis, Trail and south to the Canada-United States Boundary was carried out because of concerns about possible effects on wells during project construction activities and the formation of a reservoir at elevation 424 m. As part of this inventory, a number of wells in the Oasis area were pump tested

briefly so that well performances prior to any construction activity would be known. Special attention was also given to a review of the situation at Trail, Montrose and other communities located on the left bank of the Columbia River downstream from the proposed dam.

3.2 OASIS - RIVERVALE AREA

The community of Oasis consists of two parts. The lower part is on a low terrace at elevation 480 m along the old Trail-Castlegar Highway. This part of the community is supplied by a small water system serving about 50 connections. The source for this system is two drilled wells located about 20 m above the community. The District has another drilled well at the same location but it is not being used at present.

The Oasis system, which does not have meters, operated entirely by gravity. Water was syphoned from the two wells to a covered concrete reservoir, which has a capacity of about 70 m^3; from the reservoir the water flows by gravity into the distribution system. The system was quite adequate except in the period of high demand during the summer months. One well was used during the low demand period; it produced 0.57 l/sec (7½ igpm) with the present syphon before recent redevelopment work. We estimate that the existing syphon arrangement probably supplied about 0.83 l/sec (11 igpm) from two wells during the summer months.

The three Oasis wells are all constructed with well screens in sand. Two are 200 mm (8") diameter wells; the other is a 150 mm (6") diameter well. They are constructed in the sandy ice contact sediments which make up the terraces along the Columbia River. The terraces at Oasis are limited in extent; in fact they consist of discontinuous remnants that overlie the sloping surface of bedrock along the side of the valley (see Figure 3-2 A.). Experience with the Oasis wells shows that recharge

is adequate throughout the year in spite of the small volume of the terrace sediments and the dry climate. Brief tests of nearby rock wells as part of this study show that the fracture permeability of the rock is comparatively high; this suggests that recharge to the terrace sediments probably comes from rock.

Oasis Waterworks District has carried out redevelopment of the two wells currently in use. This has improved the performance of both wells. Attempts to redevelop the third well were not successful because of a hole in the 200 mm casing about 2½ m below ground surface. Apparently this hole had been cut to reduce the syphon lift when the well was in use. By excavating the casing and welding a patch over this hole, the well can be redeveloped and used along with the others.

In order to increase water supply, the District is planning to install pumps in two or perhaps all three of its wells. This involves bringing electric power to the well site, revisions to piping to the existing reservoir and installation of controls in the reservoir to regulate pumping. This should increase the capacity of the source to about 1½ l/sec (20 igpm). More storage may be required in the system in order to take full advantage of the increased well capacities. Pump installation should be complete by mid-August of 1982.

In summary, Oasis Waterworks District has been operating a gravity water system serving about 50 connections. It has not had sufficient capacity to meet peak summer demands. Improvement of the performance of the District's wells and the installation of pumps in two of the wells will increase the capacity of the system to relieve the shortage in the high demand period and may perhaps permit further extension of the system. Additional water can be obtained by installing a pump in the third well after the casing has been patched and the well redeveloped.

The remainder of the community of Oasis is made

up of scattered homes on a higher terrace at elevation about 550 m and a few homes on the steep slope along the road leading to the upper area. Most of these homes are supplied with water from individual wells; a few wells are shared by two users. Several also obtain water from small springs discharging from the terrace sediments.

Considering the limited extent of the sand terrace and the steep slope toward the Columbia River, the capacity of the shallow screened wells in the upper part of Oasis is quite remarkable. As in the case of the Oasis Waterworks Wells, it seems likely that much of the water in the sand is coming from the fractured rock. Conditions for recharging the rock west of Oasis are ideal because of the sparse vegetation and thin soil cover. Perhaps when a more complete cover of vegetation becomes established in future, less water will be available for groundwater recharge.

A deep well, owned by Mr. Morley Wilson at 205 Hillcrest Drive in Oasis, was drilled in 1979 through 37 m (120 ft) of sand and from there to 130 m (430 ft) in rock. At the time of construction, the casing was not tightly seated at the rock surface at 37 m and sand moved down into the well causing problems with the pump. An attempt to set a liner inside of the steel casing was not successful when the unsecured liner was lost in the lower part of the well. This liner was removed and replaced with a new liner, now secured by cable at the top of the casing. Mr. Wilson said that the well is now operating in a satisfactory manner but he would not permit us to remove the top of the pitless adapter in order to carry out a pump test. Mr. Wilson wished to have the well tested, but had not understood that it was necessary to measure drawdown during the test. Mr. Wilson reports that the well is semi-artesian.

In addition to the wells noted above, two residents use well points to supply domestic water. These obtain water from the sand.

Six domestic wells in Oasis were test pumped in May 1982, using the installed pumps. One dug well that is used only for garden and lawn watering was tested using a contractor's pump. Two of the three drilled wells owned by Oasis Waterworks District were tested using a small submersible test pump driven by a portable power plant. The tests were brief and were designed to obtain approximate well performance data which can be compared with performance data if dam construction takes place and if the District feels that performance of its wells has declined as a result. The best of the District's wells was tested for 385 minutes (about 6½ hours) to establish aquifer capacity. The cost of the test was shared between B.C. Hydro and the District as other work was requested by the District. Additional test pumping of individual domestic wells has been requested by the Oasis Action Committee. The tests will be carried out prior to dam construction.

In summary, in Oasis there are two types of wells: screened wells obtaining water from the sandy terrace sediments and wells drawing water from fractured rock. The screened wells are quite shallow; the rock wells are much deeper. The screened wells are shown by the brief pump tests to have higher capacities than rock wells but apparently both types of wells are adequate for domestic use with plenty of water for extensive lawns and gardens. Initially, a water sample was collected from a bedrock well and one from a screened well in surficial materials as a record of pre-construction water quality. At the request of the Oasis Action Committee, chemical analyses were carried out on twelve individual domestic wells. All chemical analyses are included in Appendix C.

From what we have observed at Oasis, it seems most unlikely that construction of a dam at Murphy Creek will interfere in any way with water supply from the wells now supplying the residents of Oasis. Most of the existing drilled wells completed in sand and gravel are properly constructed with well screens and would not ordinarily be disturbed by shocks from blasting. As far as we know, all of the rock wells are unlined, but

with the exception of Wilson's well mentioned previously, do not have a history of caving or instability. It is possible that shocks from blasting could cause fragments of rock to be dislodged from the walls of rock wells. Such fragments could lodge on top of a submersible pump causing it to jam when an attempt is made to remove it. This does not result in the loss of the well or significant reduction of well capacity even if attempts to fish the stuck pump are unsuccessful. Water levels in the existing wells at Oasis will not be changed by the raising of water to 424 m behind the dam.

Figure 3-2 includes an hydrogeological cross-section to illustrate groundwater flow in the Columbia River Valley near the dam site.

3.3 TRAIL MUNICIPAL WELLS

Downstream from Oasis the first wells are those supplying the City of Trail. The three wells in the main part of Trail are several years old. The most recent Trail well, completed in 1981, is at the extreme east end of the City, close to the highway crossing of Bear Creek. This well is reported to have a very high capacity. It supplies the extreme east end of the City. Present plans call for installation of large mains to that area, after which the new well can also supply water to the main part of the City.

From a discussion with the Trail City Manager, Mr. K.R. Wiesner, we understand that a change of source for the City water system is under discussion at this time. A change from the present wells to an intake on the Columbia River is being considered. Two main reasons are given by those who favour this change: complaints about the hardness of the groundwater and problems in maintaining the capacity of the City

wells. The main problem caused by hardness is scaling of hot water heaters, piping and cooking utensils. Recent attempts to restore the capacity of the City wells by acid treatment and agitation have apparently not been entirely successful.

According to Mr. Wiesner the Council is concerned about possible effects of silty water during construction of the proposed dam on the capacity of two of the City wells which are located very close to the river bank in the part of the City known as Sunningdale.

We obtained from Mr. Wiesner chemical analyses of water from City wells in each of the areas, namely Sunningdale, East Trail and Bear Creek. These have been compared to analyses of water from the Columbia River at a site upstream from Trail (Station 00BC08NE0004, Stoney Creek Pumphouse) in Water Quality Data 1961 - 1971 published by Environment Canada. A comparison of the analyses from Trail shows that all of the major cations and anions in the groundwater are 2 to 3 times as high as in the River water; the total dissolved solids and total hardness are also 2 to 3 times as high. This information is summarized in Appendix C.

The water from the new Bear Creek well is much less mineralized than that from the wells at Trail. Its water is in many respects quite similar to Columbia River water except that sulphate is about twice as high as that in the River. However from the location of the well, which is on the fan of Bear Creek 100 m or more from the River, there is virtually no possibility that the well can be drawing water from the Columbia, especially in February when the test was carried out.

The evidence strongly indicates that the Trail wells do not draw water through the river bank from the Columbia River although water levels in the wells fluctuate with water levels in the River.

They obtain groundwater from the thick ice contact deposits in which they are constructed. Some of the groundwater may be "underflow" of the Columbia, particularly at times when the River is rising rapidly but most of it is water moving through the valley fill toward the River. In our opinion silty water from construction upstream at Murphy Creek will have no effect on the wells supplying the City of Trail.

Figure 3-2 includes a schematic hydrogeological cross-section to illustrate groundwater flow patterns in the area of the Trail Wells. The log of Trail Well No. 2 is included on the cross-section.

3.4 TRAIL TO CANADA-UNITED STATES BOUNDARY

Starting at Bear Creek there is an area along the Columbia River, extending downstream for about one kilometer along the lower road, which is supplied with water from wells. There are several individual wells which supply small commercial establishments as well as a community well which supplies several commercial buildings and several homes. Conditions are reported to be very favourable for wells in that area and water quality is good.

Along the main Waneta Road there is a private water utility called Green Gables Waterworks Ltd. This system, owned by two local residents Mssrs. King and Worley, serves about 100 connections from a small un-named Creek supplemented in the summer months by water from an old drilled well constructed in 1962. Most of the connections on the Green Gables system are domestic users although the system also serves a drive-in theatre. The capacity of the well has decreased in recent years, probably mostly because of corrosion and encrustation of slotted pipe which was used instead of a well screen. Green Gables Waterworks is now constructing a new screened well near the existing well to replace or supplement the existing well.

Well construction should be completed by mid July of 1982.

The Green Gables well draws water from a sand and gravel aquifer resting on rock. A condensed log of the old well is as follows:

0 - 3.6 m	(0 - 12 ft)	coarse gravel
3.6 - 15.2 m	(12 - 50 ft)	mostly till and stony clay
15.2 - 46.6 m	(50 - 153 ft)	sand with clay
46.6 - 62.8 m	(153 - 206 ft)	sand and gravel
at 62.8 m	(at 206 ft)	rock

The static water level is about 43 m (140 ft), probably about the same as River level. Considering the type of material above the aquifer, the distance from the River and the slope of the side of the valley, there is virtually no chance that River water can reach this well or that it can be affected by silty water in the River.

Between the Green Gables Waterworks system and Beaver Creek there are several domestic wells drilled in rock. Two 400 mm diameter wells at the mouth of Beaver Creek Supply the Village of Montrose by way of a pipeline to tanks above the Village. One of these wells was constructed in 1961; the second well was completed and tested in 1982 and has not yet been put in service. Both wells are completed in sandy ice contact deposits which have high transmissivity. A number (7?) of testholes drilled in the vicinity of the wells show that the ice contact deposits are very heterogenous and extend 100 m or more below the Columbia River. The water in the aquifer probably consists of Beaver Creek underflow, groundwater moving toward the Columbia River and perhaps also a small amount of Columbia River underflow. Although both wells are quite close to the Columbia River, there is virtually no possibility that they could be affected by silty water in the Columbia.

From Beaver Creek to the United States Boundary there are no wells near the Columbia River. At Columbia Gardens south of the Trail Airfield there is an industrial park owned by B.C. Development Corporation. This presently consists of one group of factory buildings now used as a warehouse. In the development of the park a well was constructed to supply water to occupants of the park. This well has not been used up to the present time. It is located about ½ km from the Columbia River in an area where groundwater movement is toward the Columbia River. It would not be affected by changes in quality of water in the River.

4.0 IMPACTS OF MAINTAINING A RESERVOIR LEVEL OF 424 m on HIGH WATER TABLE AREAS

The consequences of maintaining a reservoir surface elevation of 424 m can best be predicted if the existing geology and hydrology are well understood. There are a few places in the study area where existing buildings fall within what can be considered a transition area - that is, the buildings are located on ground below elevation 428 m and above 424 m. This 4 m transition zone was considered for the purposes of this study to be the only area where an increased water table elevation could have an adverse impact in terms of flooding of basements. Generally, precise subsurface information from which it is possible to contour groundwater levels is not available. Using existing information, a conceptual hydrogeological cross-section (Figure 3-1) has been drawn in the Castlegar area where high water tables are of greatest concern.

4.1 CASTLEGAR AREA

4.1.1 Geology, Topography and Groundwater Hydrology

The geology and topography are important in a discussion of the groundwater hydrology of the Castlegar area. As noted in Section 2.0, there is much evidence that the northern part of the City and the point of land on which Selkirk College is built, are underlain by a moraine deposited by an ice tongue which moved down the Kootenay River Valley or perhaps down Pass Creek. The material deposited by the ice can be best described as ice contact deposits. These deposits consist of a jumbled mixture of gravel, sand, silty sand, silt and till with scattered

large boulders. The nature of these materials is particularly well shown by the logs of water wells which were drilled by the cable tool method. Some of the intersections of "silty gravel" in the recent testholes drilled by the Becker method may actually be till. The till of this area tends to be a sandy, silty, gravelly till rather than the clay-rich till of the Prairie region.

There is much evidence that the final shaping of the topography in the Castlegar area was accomplished by extremely high flows of water down the Kootenay River, and perhaps also down the Columbia River, when a large glacial lake (or lakes) was suddenly drained following the collapse of an ice dam. Torrential gravel, deposited at the end of this flood, is found upstream along the Kootenay River between South Slocan and Thrums and downstream on the Columbia River especially along the east bank. The steep-sided, closed depressions within the northern part of the City are probably kettles, formed by the melting of buried blocks of ice. They may have been later modified by the flood. Other closed depressions, with gently sloping sides and a rather streamlined form, are probably scour hollows eroded by the flood waters. Several of these may be seen at Ootischenia.

The ice contact deposits underlying the north part of the City are very permeable when considered as a whole even though they contain irregular patches of materials of low permeability. This is clearly shown by experience with high to medium capacity water wells located in North Castlegar. Because of the high permeability of the underlying materials, the water table under North Castlegar is almost flat and closely follows changes in the elevation of the surface of the Columbia River. Conditions in the Selkirk College area are similar. There are no detailed pumping test data available from wells in North Castlegar, from which transmissivity and permeability may be calculated.

4.1.2 Character of the Groundwater Flow System under North Castlegar

The groundwater flow system under North Castlegar at times of constant River level, involves flow of groundwater toward the River caused by direct recharge and also by recharge from the side of the valley (see Figure 3-1). Direct recharge comes from precipitation and from the watering of lawns and gardens. The recharge from the side of the valley includes surface run-off in winter and early spring, and year-round subsurface recharge from the underlying rock. Because of the location of North Castlegar, recharge from the side of the valley is probably quite small.

At the present time there is groundwater flow under North Castlegar from the Columbia River and back to the Columbia River further downstream. This flow is caused by the small gradient of the River as it flows past Castlegar. If the water elevation is raised to 424 m by dam construction, the gradient past North Castlegar will be insignificant so this small component of groundwater flow will stop.

In addition to the groundwater flows outlined above, changes in the level of the River induce groundwater flow in and out of the permeable materials under North Castlegar and the Columbia River terraces.

If there were no groundwater recharge in the surficial materials under North Castlegar, the water table under the area would follow the water level in the River with a time lag depending largely on the permeability of the sediments. Under conditions of no recharge, the maximum elevation of the water table after dam construction would be 424 m.

In the actual case there is recharge to the sediments underlying North Castlegar. If the River level were held constant, the water table would rise above River level during times of recharge by an amount depending on:

1. The amount and rate of recharge.

2. The coefficient of storage of the sediments (the volume of water stored in a unit volume of sediment) above the water table.

3. The transmissivity of the sediments. This is a measure of the ability of the sediments to transmit water, taking into consideration both permeability and thickness.

4. The geology of the sediments which may, because of anisotropy and rapid lateral changes in permeability, lead to complex local flow systems.

In attempting to estimate maximum changes in the water table, the short period of most rapid recharge - which is likely to occur only in early spring - is of concern. Summer storms produce very little recharge because summer rain tends only to replenish the soil moisture deficiency during summer drought. Autumn storms, even after the end of the growing season, supply little recharge water because of the soil moisture deficit which exists at the end of the summer drought. Winter and early spring is the only time of significant recharge, depending on climatic events which occur in any particular year.

For example, let us consider a worst possible condition in early spring with snow on the ground where a combination of warm weather and heavy rain supplies 15 cm of water in a few days. If the coefficient of storage of the sediments is assumed to be .1 (which is low for a water table aquifer), the rise in the water table, assuming no flow downward or toward the River, would be 1.5 m. If the trans-

missivity is fairly high, as has been shown by pumping tests of the old Castlegar wells, the rise would be much less than 1.5 m because there would be continuous flow downward and outward toward the River. Near the shore of the Columbia River, the rise in the water table would obviously be much less because of rapid flow to the River.

From the previous discussion it would seem that the largest local rise in the water table which can be expected above a static water table at elevation 424 m would be about 1.5 m to 425.5 m. This could occur only under very unlikely climatic conditions and in a place where transmissivity is rather low. Because the sediments under Castlegar are everywhere quite thick, transmissivity is usually quite high.

Obviously these calculations are very rough. They are only included to indicate what data are required to bring them closer to reality. In order to predict what may happen in the low areas of North Castlegar which are not along the shoreline, the response of the water table to the highest rate of recharge in early spring, taking into consideration simultaneous changes in River level, should be examined.

4.1.3 Impacts of 424 m Reservoir Elevation

The map (218-C11-X48) of North Castlegar along with drill hole logs and the water level data sheet (Table A-3) in the Thurber Consultants Ltd. Report, indicate that the topographic low areas in North Castlegar will not be subject to flooding, even under unusual conditions, as long as the reservoir height does not exceed 424 m elevation.

An examination of the data from the Thurber drilling program between Oasis and the Keenleyside Dam shows that 39 holes

were drilled using a Becker drill. They varied in depth from about 9 m to about 63 m. All were equipped with 25 mm diameter plastic piezometers. Of the total 39 holes, 18 are dry, one more is probably dry and 11 had water in them throughout the period July 3 through December 9, 1981. The remaining 9 had water in them for part of the year in 1981.

The elevations of the tops of the casings have been determined so that the elevation of the water table is known. Observations of most piezometers were made in 1981 on July 3, July 10, October 17, November 4 and December 9. All but one show water level elevations and elevation changes which probably are closely related to variations in the water level in the Columbia River. The exception is 81-2 at the mouth of Pass Creek. The water elevation in 81-2 is consistently higher than that in the other piezometers and higher than the River. The water elevation in 81-2 may be controlled by Pass Creek or it may be completed in comparatively impermeable sediments with a perched water table.

The water level in most piezometers was at a maximum on July 10 when most water elevations were about 420 m. At this water elevation, only six piezometers showed water to be 10 m or less from ground surface. All of these are in the old part of the City of Castlegar. The shallowest of these are 81-30 and 81-38 where the water stood at 6.7 m below ground.

A careful examination of the bottom of the closed depressions (kettles) in North Castlegar in April, 1982 disclosed no signs of occasional flooding. An excavation associated with the modification of a sewage lift station close to the bottom of a kettle near the intersection of 9th Avenue and 6th Street, exposed undisturbed gravelly, silty ice contact deposits. There were no signs of colour mottling which is usually seen where a soil is occasionally saturated because of high water table

conditions. In the low areas, there are a few houses where basements may extend a significant distance below ground level. The floor elevation of these few basements can easily be checked. The area of possible concern is shown on Figure 4-1.

4.2 OTHER AREAS

Other areas where buildings are located on ground below elevation 428 m are in East Raspberry, Brilliant, near the Robson ferry terminal, along the road to the Keenleyside Dam and at Genelle. The previous discussion about possible shallow water tables in North Castlegar is applicable to all of these places except for the fact that they are closer to the shore of the proposed reservoir than several of the low areas in North Castlegar. Because of this, they are less likely to show sudden rises in the water table due to rapid local recharge in early spring and are therefore less likely to be subject to occasional flooding of basements.

4.2.1 East Raspberry Area

Conditions are somewhat different at East Raspberry than the other areas because of Pass Creek. The lower part of the community is located on the delta of Pass Creek. Logs of wells and testholes drilled near the highway bridge over Pass Creek show that the Pass Creek delta is made up mostly of sand and gravel. A line of 4 testholes, drilled by Department of Highways in 1956, shows that there is 3 to 6 m (10 to 20 ft) of loose, coarse sand and fine gravel overlying 7.5 to 15 m (25 to 50 ft) of sand with traces of gravel and silt, described as loose, over more sand and fine gravel.

An old (1953) water well near the bridge shows:

0	-	1.5 m	(0	-	5 ft)	yellow clay
1.5	-	4.6 m	(5	-	15 ft)	sand and gravel
4.6	-	9.1 m	(15	-	30 ft)	silty clay
9.1	-	17.7 m	(30	-	58 ft)	fine sand
17.1	-	20.1 m	(58	-	66 ft)	coarse sand

The static level on February 23, 1953 was 8.5 m (28 ft).

Another well east of the bridge shows:

0	-	13.0 m	(0	-	42½ ft)	clay, some sand
13.0	-	13.7 m	(42½	-	45 ft)	sand and gravel
13.7	-	15.2 m	(45	-	50 ft)	pea gravel and sand
15.2	-	18.6 m	(50	-	61 ft)	gravel and sand

The static level (probably in September of 1966) was 13.0 m (42½ ft).

The logs of all these holes show that the delta is quite heterogeneous, as expected when a delta is deposited by a meandering stream especially where the base level (Columbia River level) is fluctuating. In general, it seems likely that there is enough permeable material near surface so that the groundwater gradient due to upstream recharge by Pass Creek is very small in the East Raspberry area.

The elevation of the water table on the Pass Creek delta is controlled by the elevation of water in the Columbia River and probably also to some extent by the flow of Pass Creek. One of the testholes drilled in the Thurber investigations (81-2) is west of Pass Creek and probably not in the delta. It is drilled entirely in "Silt, compact, grey brown, very fine sand-trace of organics".

Four observations of water levels show that the water level is constantly 2½ to 3 m above the level in all other observation wells in the area. This may simply be because the observation well in the silt is clogged or because it is showing a local perched water table.

Areas near Pass Creek where high water table conditions may cause basement flooding are shown on Figure 4-2.

4.2.2 Benches Along the Columbia River

The situation along the benches of the Columbia River is somewhat different mainly because the permeability of the materials underlying the benches is lower than that of the North Castlegar-Selkirk College area. The logs of water wells on these benches and occasional exposures of sediments underlying the benches indicate that they are made up of ice contact materials which are mostly rather fine-grained sand, silty sand, and silt. Since the permeability of these sediments may be medium to low, the water table has distinct gradients caused by groundwater flow. Since the water table in these areas is generally at a considerable elevation above the 424 m reservoir level, the impacts of a 424 m reservoir elevation on the groundwater flow system are of no concern.

5.0 IMPACTS OF MAINTAINING A RESERVOIR LEVEL OF 424 M ON GROUNDWATER QUALITY

Possible impacts that a reservoir level of 424 m behind the proposed Murphy Creek Dam could have on groundwater quality are related to the following:

1. Changes in the quality of groundwater pumped from wells where the source of recharge for the aquifers which supply water to the wells is the Columbia River. (Of particular concern is discharge from Cancel).

2. Deterioration of groundwater quality caused by flooding of existing septic tank-tile drain field facilities or landfills.

3. Changes in the quality of groundwater pumped from wells along the Columbia River downstream of the dam, caused by suspended sediment in the River during construction of the dam.

4. Changes in the quality of groundwater in the dam site area caused by blasting during construction of the dam.

This report (page 3-3) states that, with the possible exception of the aquifer at Selkirk College, Columbia River level changes will have no effect on the quality of groundwater in the aquifers along the River because the water is not from the River.

5.1 SELKIRK COLLEGE AQUIFER

The aquifer which supplies water to the wells at Selkirk College probably contains water moving from the Kootenay River to the Columbia, which is at a slightly lower elevation.

Although the water levels in the wells constructed in the aquifer at Selkirk College fluctuate in response to River level, fluctuations in the level do not significantly change the path and the amount of groundwater flow. Raising the Columbia River level to 424 m may, however, decrease the groundwater flow from the Kootenay to the Columbia. It is not possible to predict however whether this would change the quality of water in the aquifer. The degree of change would depend on the amount of water being removed from the aquifer and the location of pumped wells. The Selkirk College wells are close to the Kootenay River side of the aquifer and the amount of water being pumped is relatively insignificant. These facts suggest that the quality of water from the Selkirk wells will not change.

It is most unlikely that, even if a higher River level in the Columbia results in more recharge to the Selkirk College aquifer from the Columbia River, water quality (particularly in regard to sediment and/or wood fibre) in the wells at Selkirk College would be affected. Sediment and/or wood fibre is not likely to enter the aquifer but rather is likely to contribute to sealing of the River bed. The Selkirk College aquifer would have to be pumped at a very high rate to induce water to move rapidly through the aquifer from the Columbia before significant effects on water quality in the wells could be expected. The amount of water removed by the College wells at present is insignificant.

Background data on quality of groundwater in the Selkirk College aquifer are available. Regular monitoring of the quality of the water from the wells at the College will reveal any trends. Small seasonal fluctuations in the water quality probably occur at the present time.

5.2 SEPTIC TANK-TILE DRAIN FACILITIES AND LANDFILLS

In Section 4.0 of this report, two areas were identified where a reservoir elevation of 424 m will result in high water tables that could cause flooding of basements:

1. North Castlegar (Figure 4-1).
2. East Raspberry (Figure 4-2).

North Castlegar is served by a wastewater collection and treatment system, so flooding of on-site sewage disposal facilities and possible groundwater quality deterioration as a result, is not of concern.

There is some possibility that a few on-site sewage disposal facilities in the East Raspberry area may be affected during the freshet of Pass Creek; that is, a high water table may interfere with proper operation of the facilities. Any houses identified as being subject to possible basement flooding due to an increase in the elevation of the water table during the freshet at Pass Creek should also be checked in regard to the elevation of on-site sewage disposal facilities.

It is possible that a few on-site sewage disposal facilities in the Genelle area near the mouth of China Creek could be affected by a reservoir elevation of 424 m. The elevation of on-site sewage disposal facilities of residences near the shoreline should be checked.

No landfill sites are known in the areas where high water tables will result from an increase in the level of the Columbia River. Therefore, deterioration of groundwater quality from flooding of existing landfills is not of concern.

5.3 DAM SITE CONSTRUCTION

Two concerns about the effects of dam construction on water quality from wells along the River are the following:

1. Possible clogging of wells downstream as a result of sediment suspended in Columbia River water from construction of the dam.
2. Quality changes caused by blasting at the dam during construction in the Oasis area, particularly introduction of sediment from the walls of open borehole rock wells.

Other than in the case of the Selkirk College aquifer, as noted earlier in this report, all evidence indicates that wells along the Columbia River, including those at Trail, do not receive recharge by direct filtration from the Columbia River. Instead, such wells obtain groundwater from flow systems moving toward the River. Therefore, the chance that sediment-laden water will have any effect on the quality of groundwater from wells along the River is remote. Further, even if induced infiltration by pumping should occur, the filtering capacity of the aquifer, along with very low velocity of water moving toward the wells, would insure that suspended sediment would be carried only a very short distance.

There is no reason to believe that the quality of water from wells supplying domestic water in the Oasis area will be affected because of blasting during construction of the Murphy Creek Dam. Water samples were collected in order to establish background water quality prior to construction activity. These analyses are included in Appendix C.

6.0 SUMMARY AND CONCLUSIONS

In a discussion about the possible effects of dam construction on groundwater, the area along the Columbia River between the Keenleyside Dam and the United States Boundary can be divided into two parts: that upstream from the proposed dam and that downstream from the dam.

In the upstream area there are a number of wells at an elevation considerably above the River. A typical example is the community of Ootischenia across the River from Castlegar, which has a water system supplied by several wells. Other places, for example the community of Brilliant, are close to the River and close to River elevation. In these places the static level in the wells will rise by an amount close to the amount that the River is raised by dam construction. The effects on wells of these rises in level will be minimal; such rises however will be beneficial in that the capacities of the wells will be increased by a small amount. Water quality will not be changed.

The main concern in the area along the River above the proposed dam is possible flooding or waterlogging in places where raising the River level to 424 m would cause a rise in the water table. (Naturally, we are considering here areas above the 424 m shoreline). There are several small areas within North Castlegar and possibly an area near the mouth of Pass Creek which may be affected. The unconsolidated materials under North Castlegar are believed to be permeable enough to prevent "mounding" of the water table during times of maximum groundwater recharge. The elevations of basement floors of several buildings should be checked to make sure that they are at elevation 425.5 m or higher. The water table in the delta near the mouth of Pass Creek may become higher during the annual freshet on Pass Creek than it does now

because of the backwater effect caused by ponding of the Columbia River at 424 m elevation.

Downstream from the proposed dam the main concern is whether suspended sediment in the water of the Columbia River, caused by construction activity at the dam, will cause clogging of wells located along the River. The main wells located close to the Columbia are two wells supplying the City of Trail and two wells supplying the Village of Montrose. A few domestic wells are also close to the River; most are far enough from the River so that there can be no possible effect.

All evidence indicates that none of the wells, even the large Trail wells, receive water by direct infiltration from the Columbia River and that groundwater in the bench sediments along the River is moving toward the River. For this reason, and also because the velocity of water (if induced infiltration occurs) is very low, there is hardly even a remote chance that sediment-laden water will have any effect on wells along the River below the proposed dam. The terms of reference (paragraph 3) state that: "The Consultant should assess the annual variability of well water levels in the Oasis-Rivervale area and show how these are related to River level fluctuations." Water levels of wells in that area are not related to the level of water in the Columbia River. The sandy sediments which supply water to the Oasis Waterworks District wells overlie rock at an elevation above the proposed reservoir level of 424 m. Water levels in these sediments are not related to present or proposed River levels. Rock wells are in use only in the upper part of the community where water levels are close to surface at elevations much higher than the River. Water level in the River has no effect on these wells.

As far as we know all of the rock wells at Oasis are in use so none are available for use as observation wells. The same is true of the screened wells except at the Oasis Waterworks District well field, where two out of three wells are in use and will probably continue in use after installation of pumps. However, the extra well owned by the District is very close to the operating wells so the water level in it would be strongly influenced by local pumping.

The water well location map shows a group of several shallow drilled wells on a higher bench at an estimated elevation of about 640 m located west of Oasis close to the gas pipeline. They are completed in sand over rock. A visit to the area indicates that they have probably been abandoned: one of them may be available for an observation well. Water levels at these wells are probably not related to water levels at Oasis but an observation well at this location would give an idea of how the water level fluctuates away from the direct influence of human activity. In order to obtain data on water levels in rock at Oasis, it would be necessary to drill a rock well, preferably a hundred metres or more from any of the existing rock wells.

Since it is clear that water levels in rock or in the sediments at Oasis are not related to the water level in the Columbia River, there is little reason to observe water levels at Oasis. There is a possibility that local residents dependent on rock wells might claim that water levels in their wells had been changed by blasting during dam construction. An observation well in rock at a location closer to the construction site than domestic wells which are in use would help to show whether or not such a change had taken place.

7.0 RECOMMENDATIONS

We conclude from this investigation that the construction of the Murphy Creek dam will have only marginal effects on groundwater upstream from the dam and no effect on groundwater downstream from the dam. Therefore we do not find it necessary to recommend any action to mitigate impacts.

The following things would be helpful, however, in better defining the existing situation:

1. Continue observations of six water level piezometers in Castlegar on a monthly basis, except during peak run-off when the observations should be more frequent. The piezometers are identified on Figure 4.

2. Install three small diameter well points or piezometers on the Pass Creek Delta. The areas where the piezometers should be installed are shown on Figure 5.

3. Install an observation well in rock between existing rock wells at Oasis and the dam site to confirm that blasting does not affect water levels in rock wells.

4. Take regular observations of the chemical quality of groundwater pumped from the Selkirk College aquifer to monitor any changes in water quality which may result from creation of a reservoir at elevation 424 m.

8.0 SELECTED REFERENCES

Environment Canada. 1974. Water Quality Data British Columbia 1961-1971

Fulton, R.J. and Smith, G.W. 1978. Late Pleistocene Stratigraphy of South-Central B.C. Canadian Journal of Earth Sciences, V. 15, pp. 971-980.

Hydroelectric Generation Projects Division, British Columbia Hydro and Power Authority. March, 1981. Columbia River Murphy Creek Project Feasibility Study. Report No. H 1335.

Hydroelectric Generation Projects Division, British Columbia Hydro and Power Authority. August, 1981. Murphy Creek Project Geology and Landforms. Report No. H 1280.

Ker Wood Leidal Associates Ltd. February, 1981. Phase 1 Study. Impact of the Murphy Creek Hydroelectric Dam on Municipal Services in the Castlegar Region.

Ministry of Environment. Groundwater Hydrology Section. Water Well Maps and Well Logs.

Pacific Hydrology Consultants Ltd. 1981. Murphy Creek Project Feasibility Study. Effects of Proposed Murphy Creek Dam on Groundwater and Wells along the Columbia River.

Robinson, Roberts & Brown Ltd. 1971. Completion Report, Production Well No. 3 for the City of Trail. pp. 2 and 3.

Thurber Consultants Ltd. 1982. Murphy Creek Reservoir Shoreline Assessment.

KEY PLAN

LEGEND:

- City, town, or settlement
- Existing dam
- Limit of drainage basin

SCALE IN KILOMETERS

20 0 20 40 60 80 100

MURPHY CREEK PROJECT

FIGURE 1-1

AREA LOCATION MAP

Base from B.C. Hydro Map No. 218-C14-8120 March 1981

SCALE 1:2500000

MURPHY CREEK PROJECT

FIGURE 1-2

WELL INVENTORY INDEX MAP

Base taken from B.C. Hydro Map No. 218 · C14 - D121 March 1981

SCALE 1: 100,000

444,000E

445,000E

446,000E

LEGEND

- Location of drilled water well
- Location of dug water well
- Spring
- GS — Surface Water Source (Gravity System)
- SS — Stream Source
- Shoreline Areas where depth to water will be less than 4 m.

5,466,000N

5,465,000N

HUGH KEENLEYSIDE DAM

COLUMBIA RIVER →

PIT RIVER

22009 436 27

1 2 3 7 8 9 10 11 12 13 14 15 16

200 0 200 400 Metres

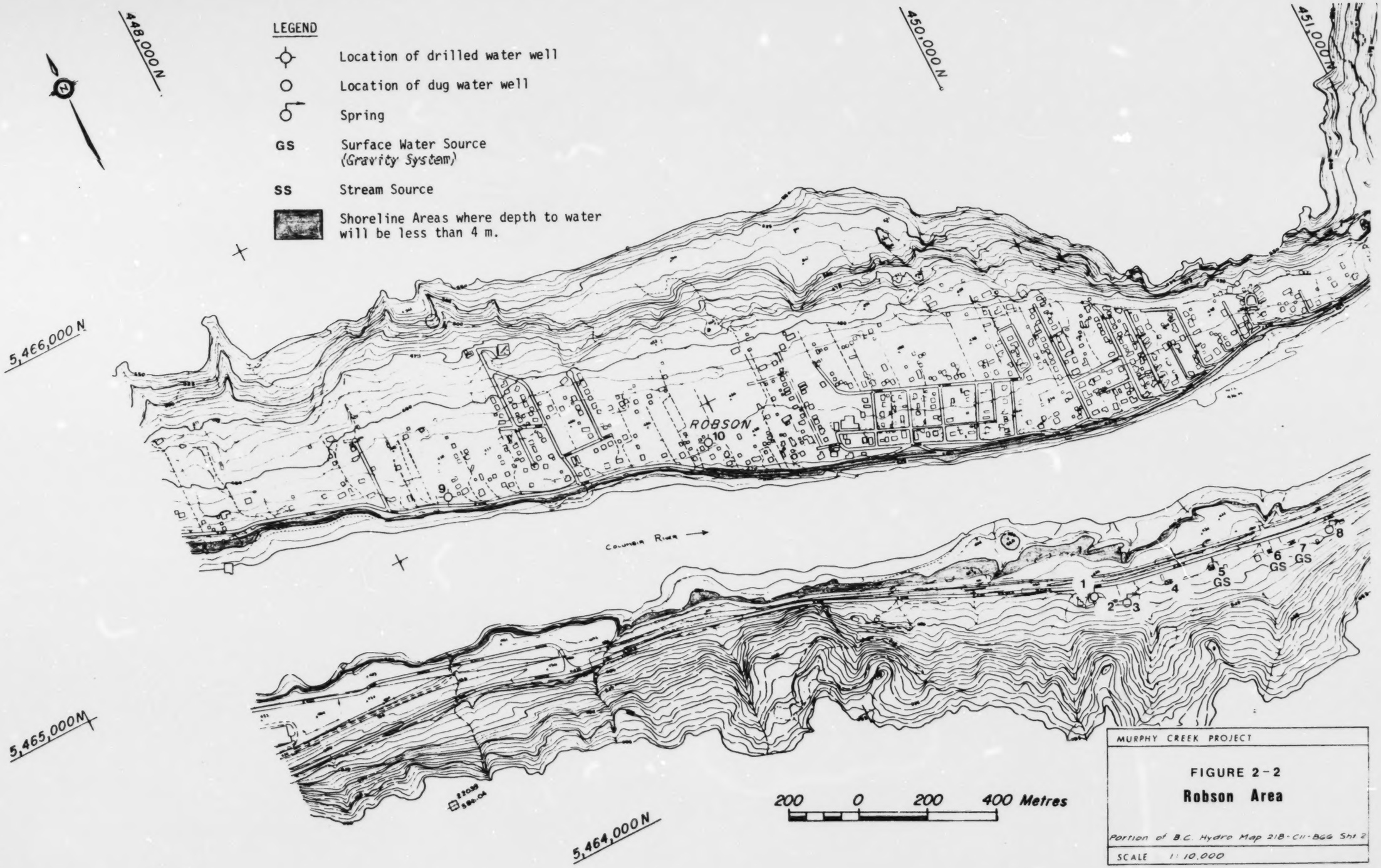
MURPHY CREEK PROJECT

FIGURE 2-1

Keenleyside Dam - Robson Area

Portion of B.C. Hydro Map 218-C11-BGS Sht1

SCALE 1:10,000



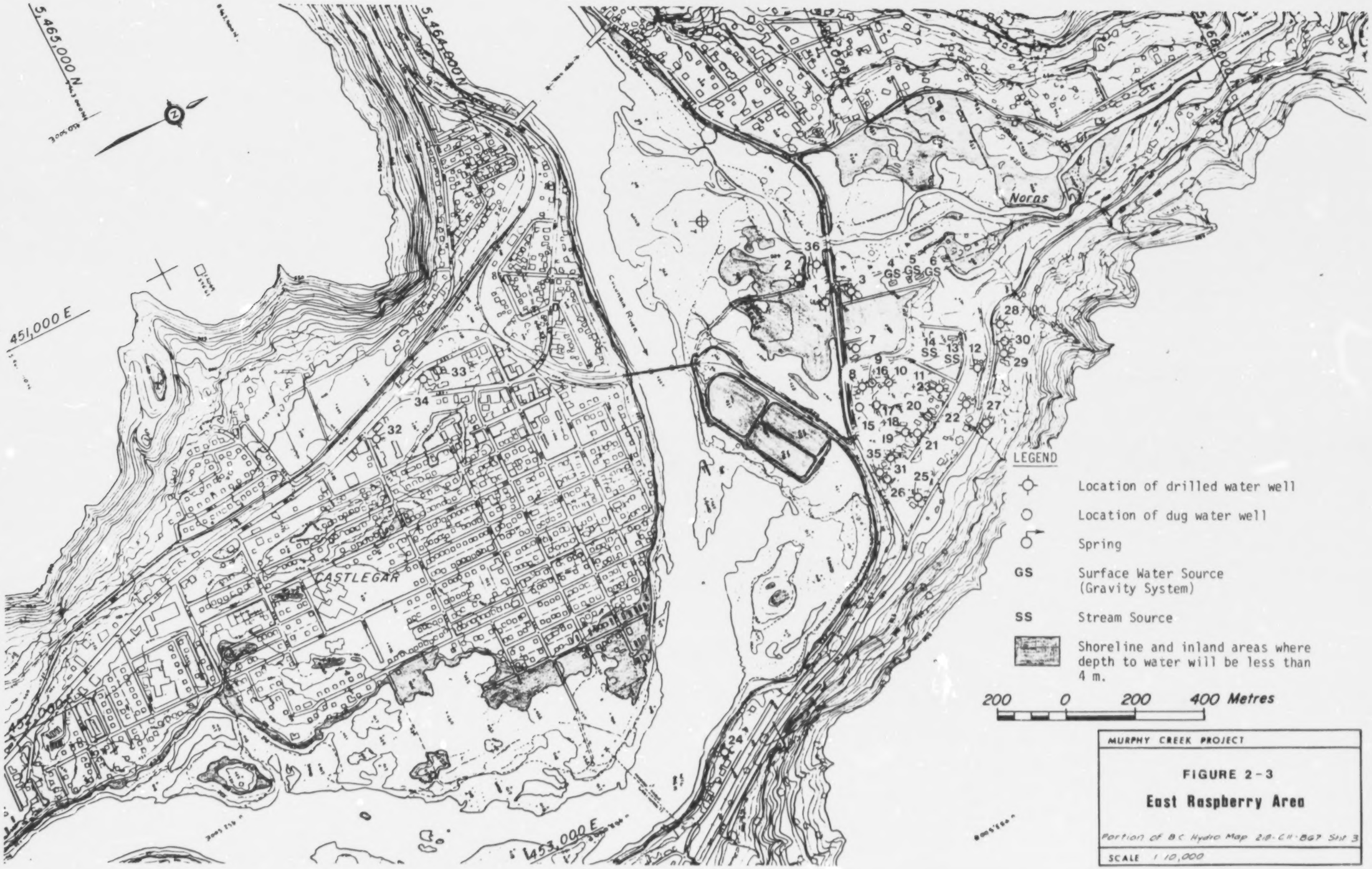
MURPHY CREEK PROJECT

FIGURE 2-2

Robson Area

Portion of B.C. Hydro Map 218-C11-BGG Sht 2

SCALE 1:10,000



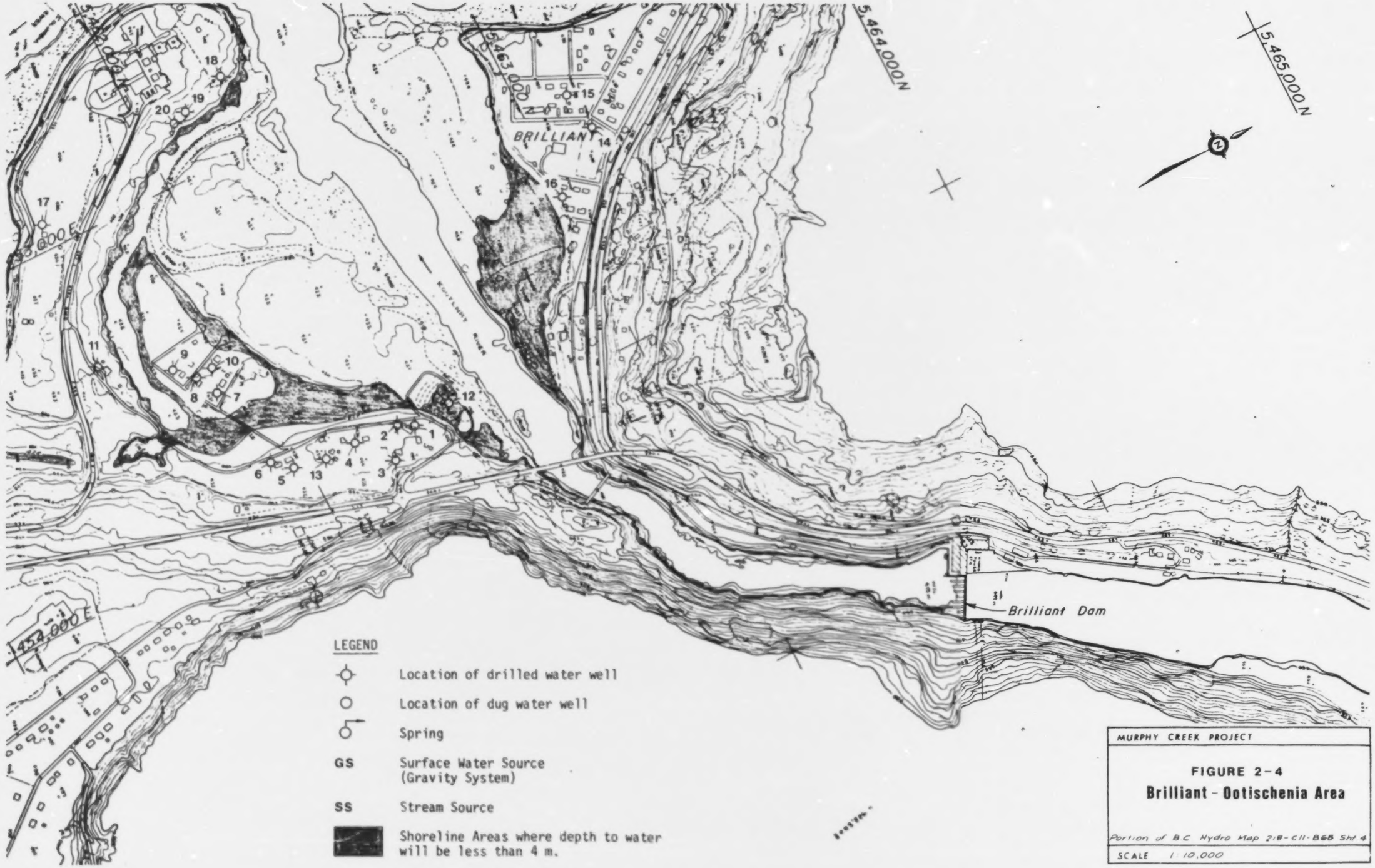
MURPHY CREEK PROJECT

FIGURE 2-3

East Raspberry Area

Portion of B.C. Hydro Map 218-CH-867 Sht 3

SCALE 1:10,000



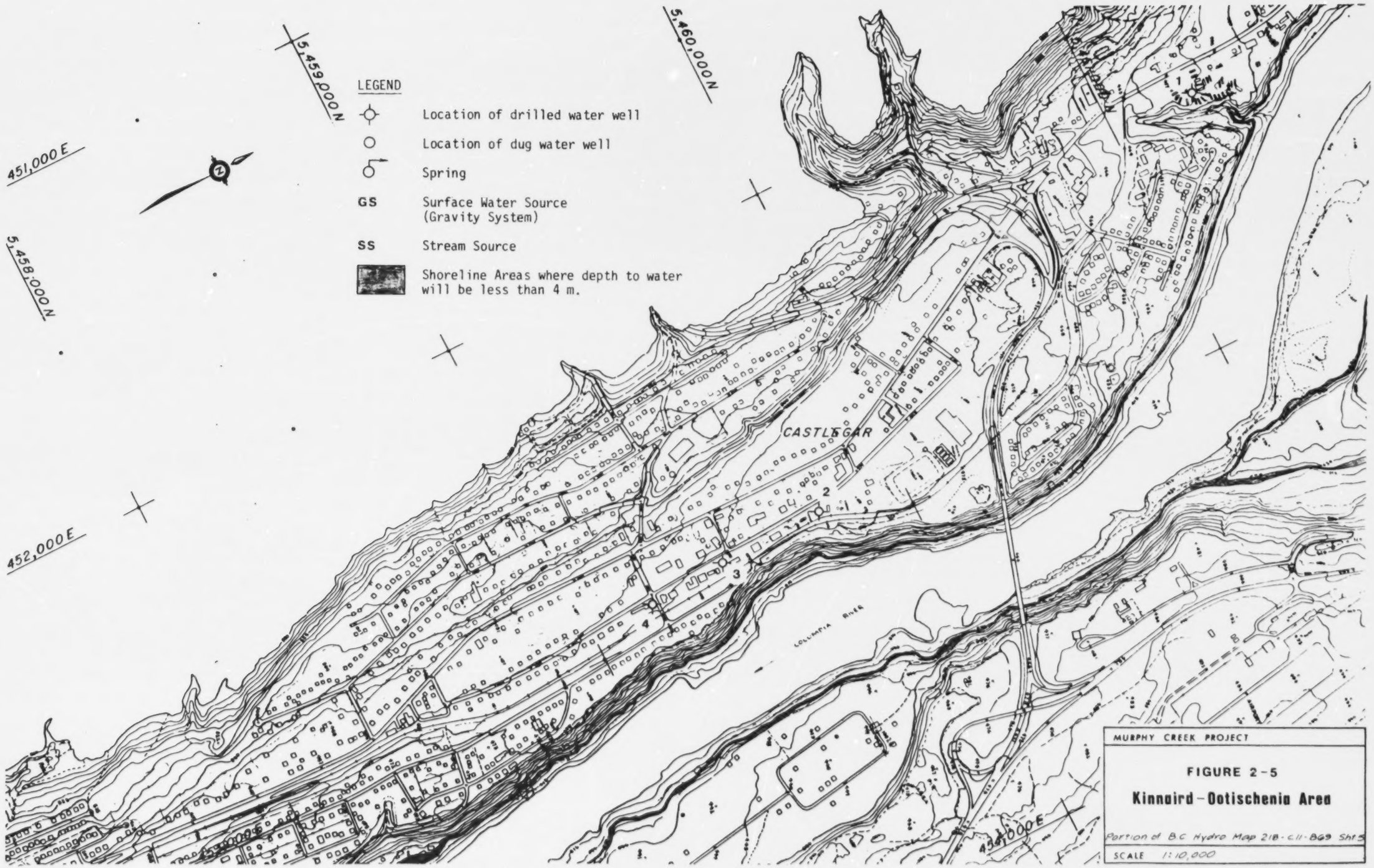
MURPHY CREEK PROJECT

FIGURE 2-4

Brilliant - Ootischenia Area

Portion of B.C. Hydro Map 218-C11-B68 Sht 4

SCALE 1:10,000



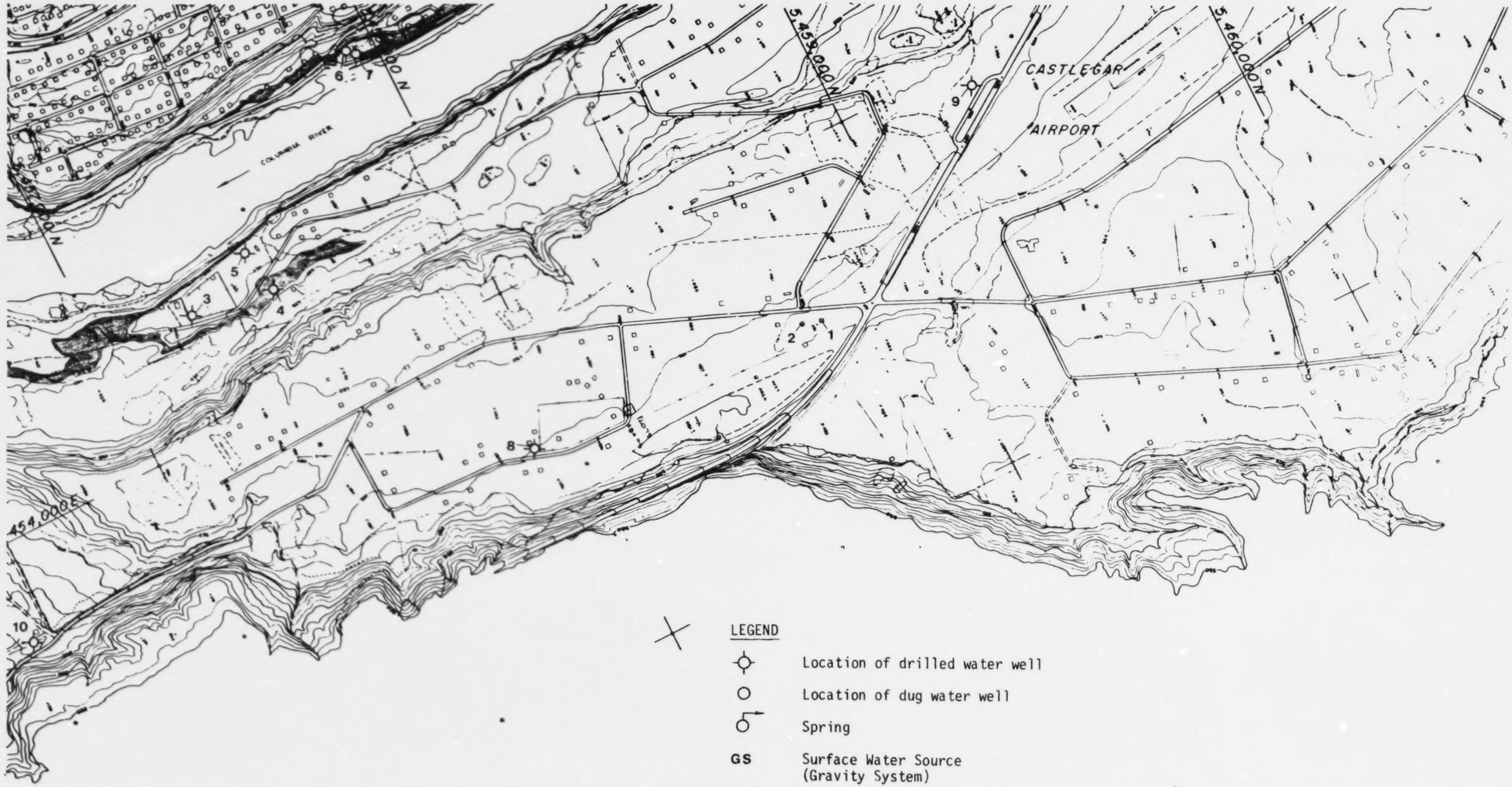
MURPHY CREEK PROJECT

FIGURE 2-5

Kinnaird - Ootischenia Area

Portion of B.C. Hydro Map 218-C11-869 Sht 5

SCALE 1:10,000



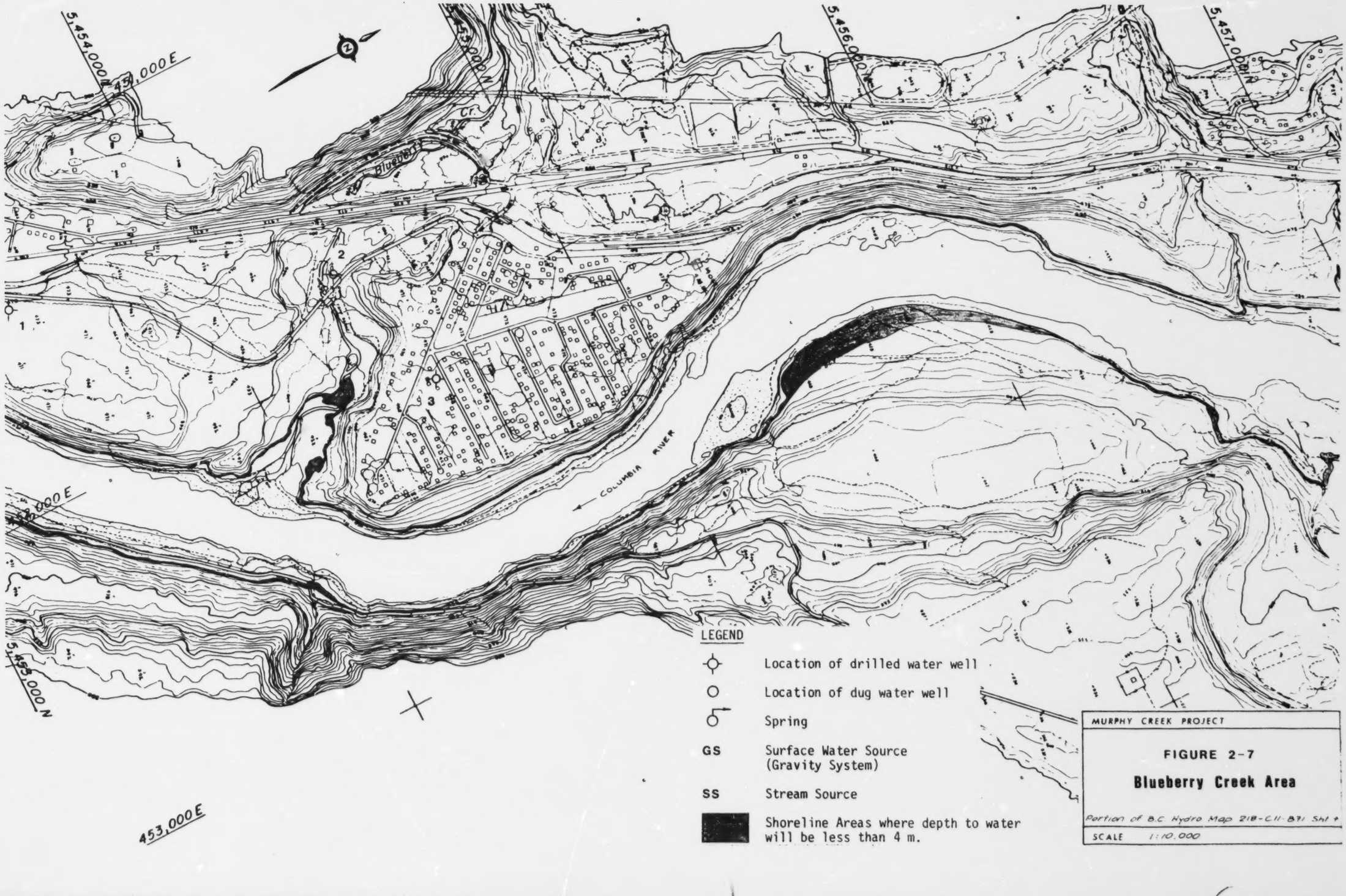
MURPHY CREEK PROJECT

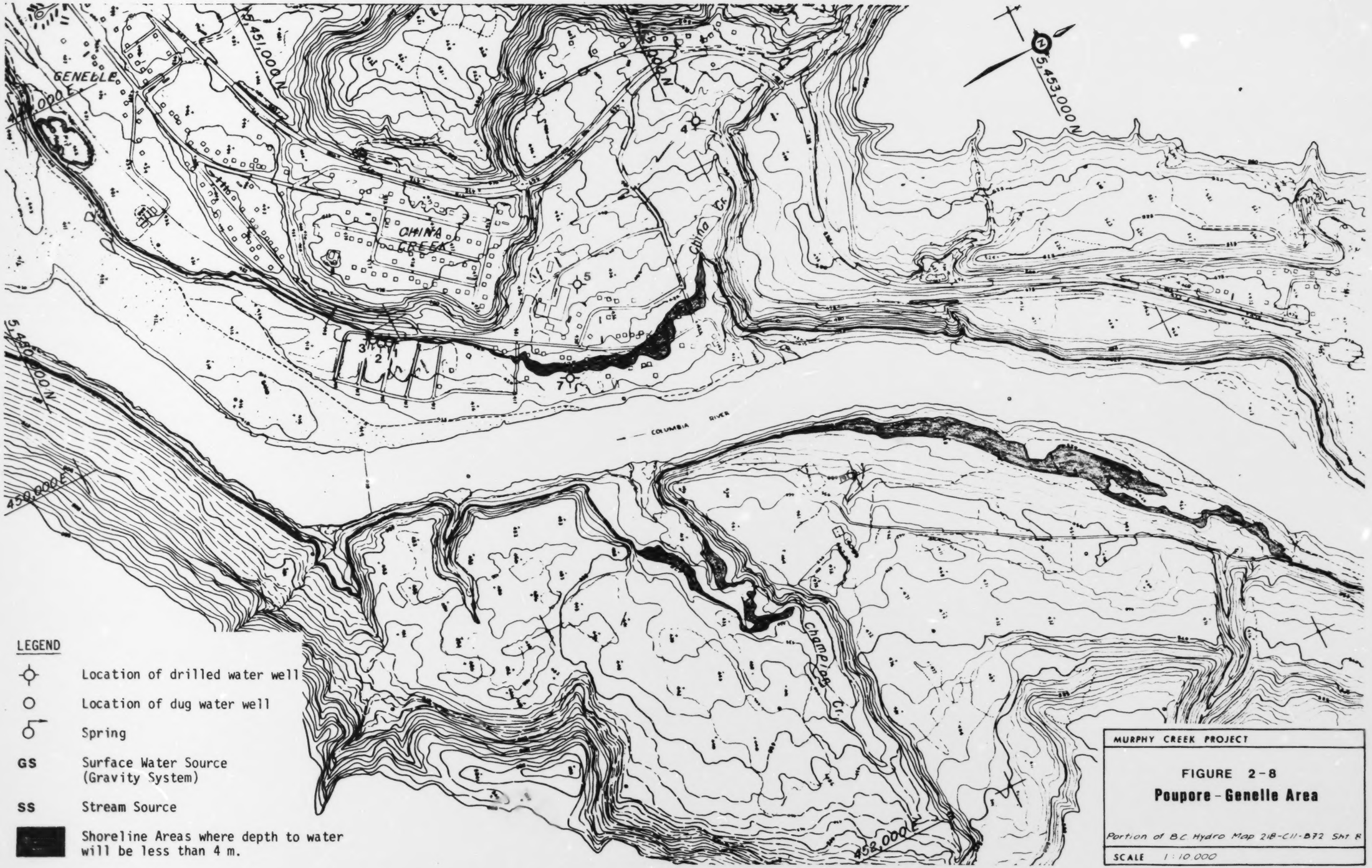
FIGURE 2-6

Ootischenia Area

Portion of BC Hydro Map 2in CII-B70 Sht 6

SCALE 1:10,000


5,454,000N
453,000E
Blueberry Cr.
5,455,000N
5,456,000N
5,457,000N
COLUMBIA RIVER
453,000E
LEGEND
Location of drilled water well
Location of dug water well
Spring
GS
Surface Water Source (Gravity System)
SS
Stream Source
Shoreline Areas where depth to water will be less than 4 m.
MURPHY CREEK PROJECT
FIGURE 2-7
Blueberry Creek Area
Portion of B.C. Hydro Map 218-C.11-B91 Sht 7
SCALE 1:10,000



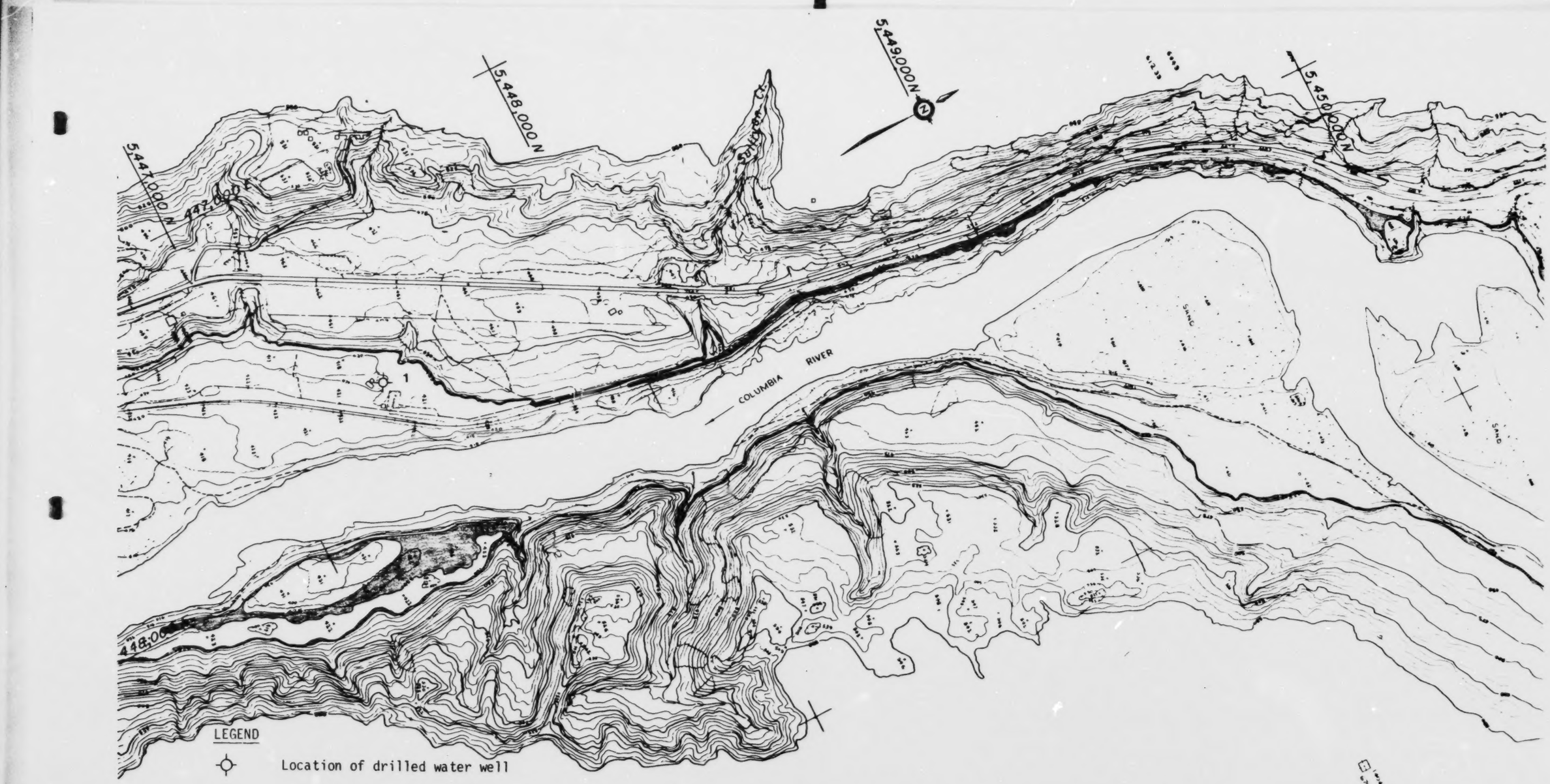
MURPHY CREEK PROJECT

FIGURE 2-8

Poupore - Genelle Area

Portion of B.C. Hydro Map 218-C11-B72 Sht 8

SCALE 1:10,000



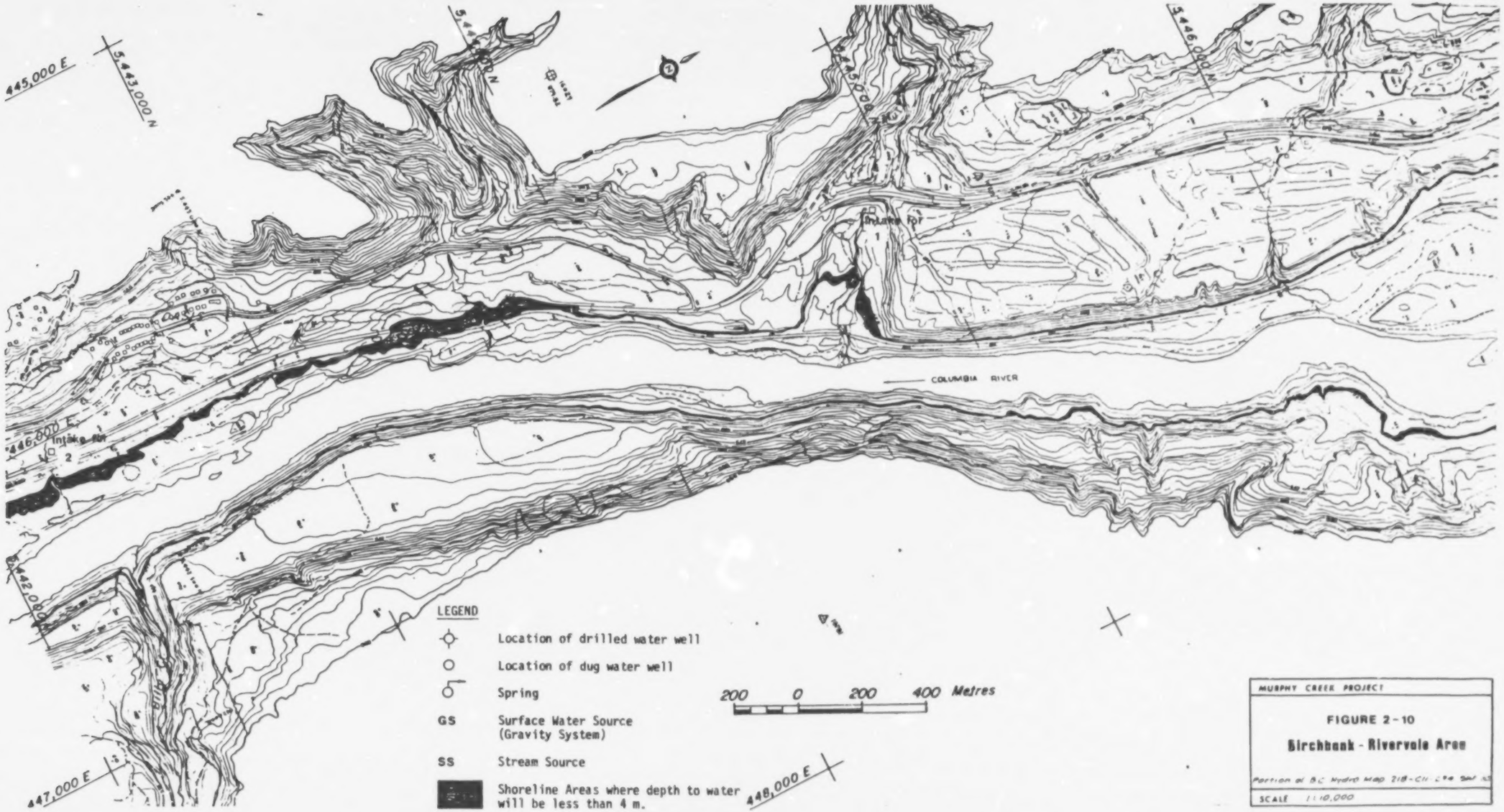
MURPHY CREEK PROJECT

FIGURE 2-9

Sullivan Creek Area

Portion of B.C. Hydro Map 218-C11.373

SCALE 1:10,000



MURPHY CREEK PROJECT

FIGURE 2-10

Birchbank - Rivervale Area

Portion of B.C. Hydro Map 218-CH.C.90 Sht 13

SCALE 1:10,000

LEGEND

- Location of drilled water well
- Location of dug water well
- Spring
- GS — Surface Water Source (Gravity System)
- SS — Stream Source

MURPHY CREEK PROJECT

FIGURE 2-11

Oasis Area

SCALE 1:5,000

LEGEND

- Location of drilled water well
- Location of dug water well
- Spring
- GS — Surface Water Source (Gravity System)
- SS — Stream Source

Warfield
TRAIL
Columbia Kootenay
Mountain
Island
Lookout Mountain
Lake Mountain
Delay Mountain
TAMARAC MOUNTAIN
Mount Maide
Creek
Montrose
Tp 8A
Tp 7A
BKE
BKA
BKC
SL 1
SL 2
SL 3
SL 4
SL 15
SL 29
SL 34
SL 40
SL 43
SL 45
SL 46
SL 48
SL 49
SL 49A
SL 51
SL 52
SL 53
SL 142
SL 146
SL 147
SL 148
SL 177
SL 182
S10
S11
S12
S13
S14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

MURPHY CREEK PROJECT

FIGURE 2-12

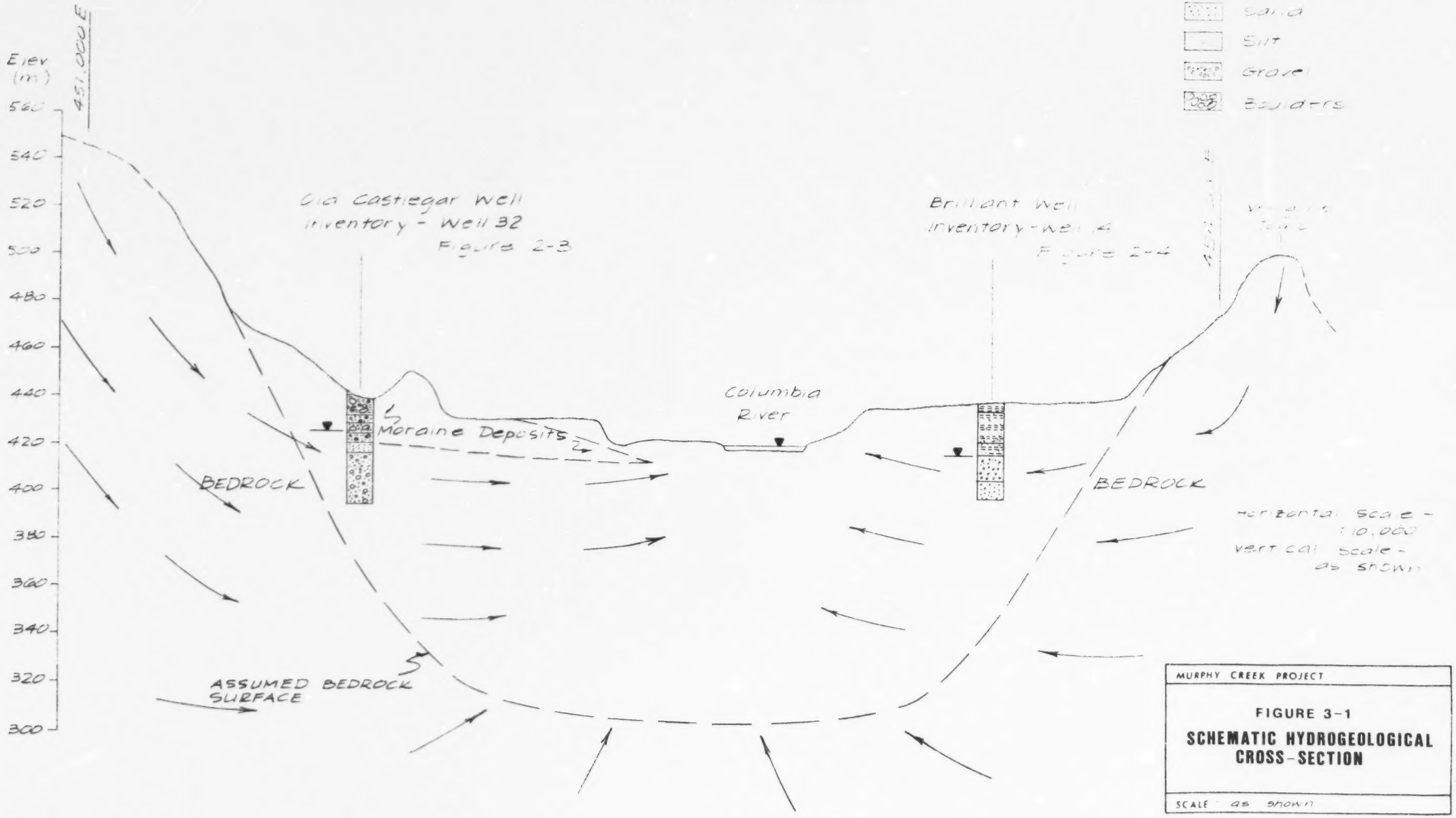
Trail - Montrose Area

Portion of Topo Map 82 F 4

SCALE 1:50,000

SCHEMATIC
HYDROGEOLOGICAL CROSS-SECTION A-A'

ALONG 5,463,000 N



MURPHY CREEK PROJECT

FIGURE 3-1

SCHEMATIC HYDROGEOLOGICAL CROSS-SECTION

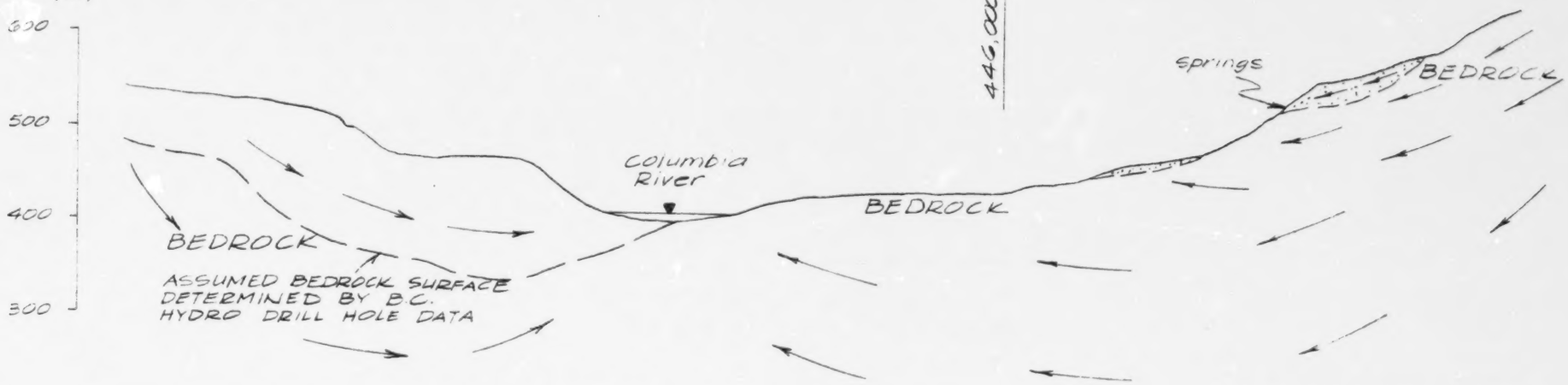
SCALE: as shown

EAST

SCHEMATIC HYDROGEOLOGICAL CROSS-SECTION B-B'

FIGURE 3-2A

WEST



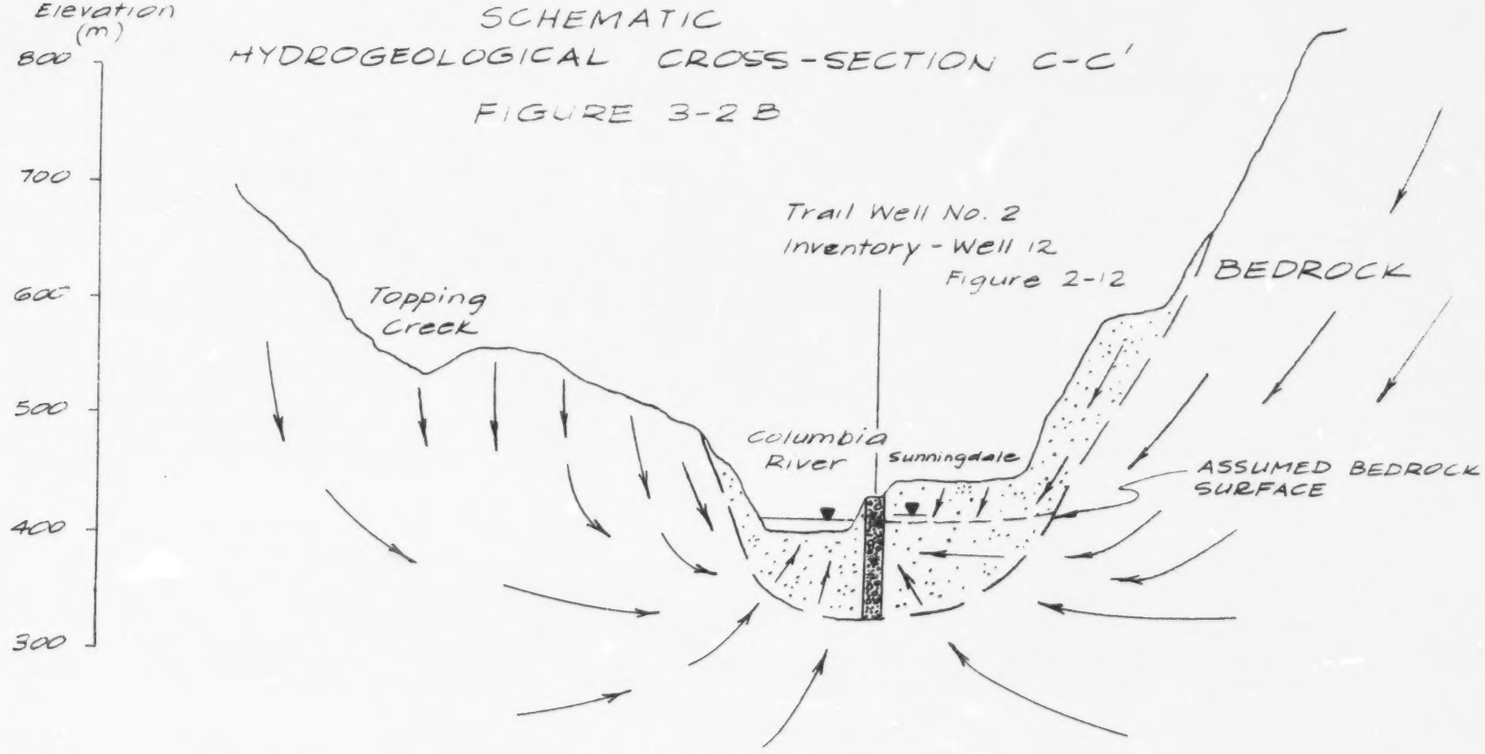
Horizontal Scale - 1:2500
Vertical Scale - AS shown

WEST

EAST

SCHEMATIC HYDROGEOLOGICAL CROSS-SECTION C-C'

FIGURE 3-2B



Direction of Groundwater Flow

Water Level

LITHOLOGY

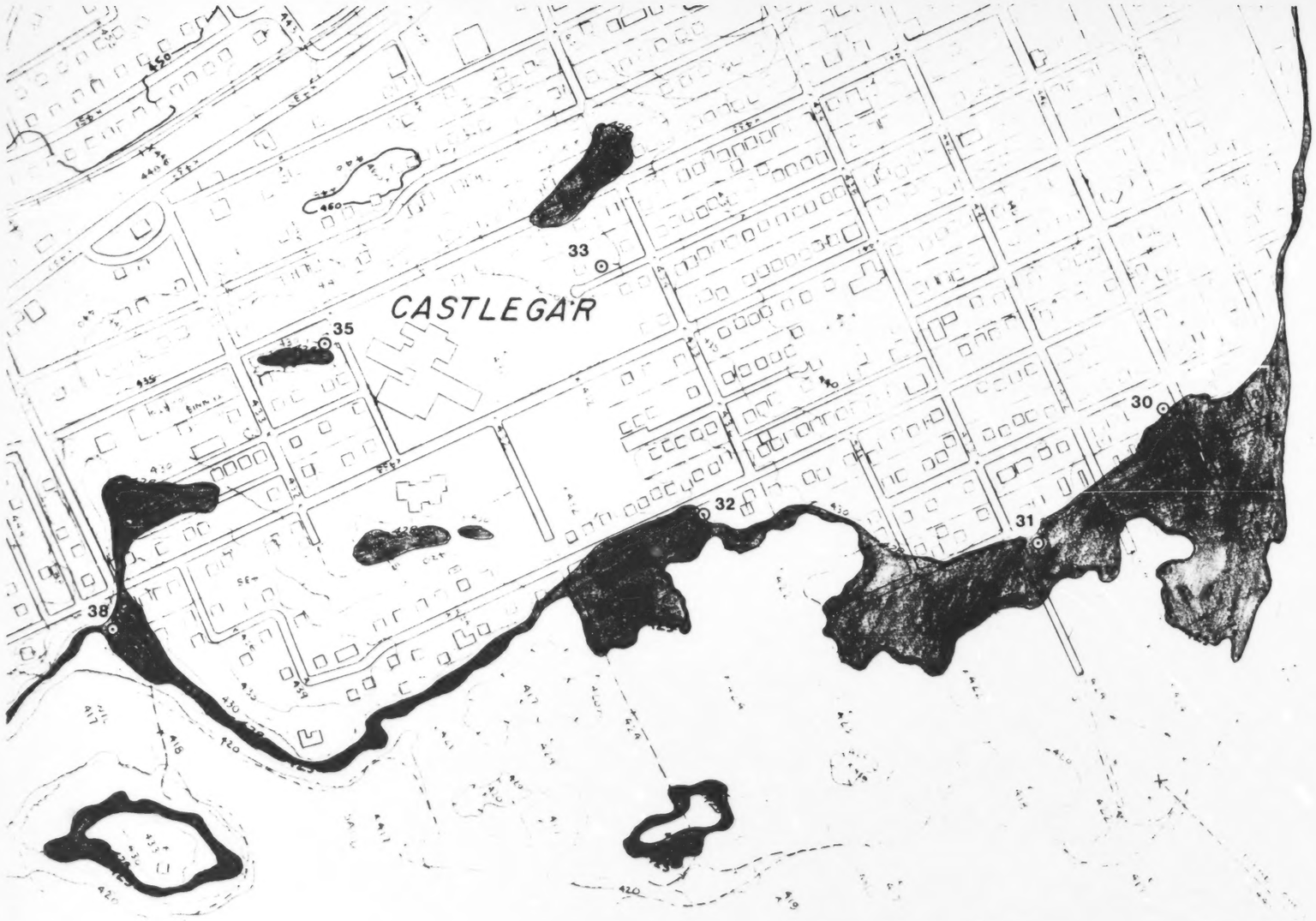
- Clay
- Sand
- Silt
- Gravel
- Boulders

Horizontal Scale - approx 1:6 000
Vertical Scale - as shown

MURPHY CREEK PROJECT

FIGURE 3-2A
3-2B
SCHEMATIC HYDROGEOLOGICAL CROSS-SECTIONS

SCALE AS SHOWN



LEGEND

Areas of Possible High Water Tables

Piezometers to be kept for Monitoring (30, 31, 32, 33, 35, 38)

MURPHY CREEK PROJECT

FIGURE 4-1

Areas in Castlegar which could be affected by High Water Tables

Portion of B.C. Hydro Map 218-C11-X48 Sht 3

SCALE 1:50,000

LEGEND

Areas of Possible High Water Tables

Areas where Piezometers should be installed

MURPHY CREEK PROJECT

FIGURE 4-2

Areas on Puss Creek Delta which could be affected by High Water Tables

Portion of B.C. Hydro Map 21H-C11-X48 Sht 3

SCALE 1:5,000

APPENDIX A

WATER WELL INVENTORY

APPENDIX A

WATER WELL INVENTORY

The water well inventory was carried out to identify and summarize information on existing water wells located along the Columbia River upstream from Oasis, where well owners may be concerned about the influence on wells of the reservoir created by the proposed Murphy Creek Dam. The inventory was later extended downstream to the United States Boundary where particular concern has been expressed about the possible effects of sediment in the River water as a result of dam construction. The results of the inventory are presented in Tables A-1 to A-12. Figure 1-2 is an index map for the water well inventory. The wells are plotted on Figures 2-1 to 2-12.

The inventory includes information from the Groundwater Section, Engineering and Inventory Branch, B.C. Ministry of Environment and information collected by a technician in the field. In a few cases water well contractors were contacted for additional information. Experience with well inventories shows that well owners often do not have detailed information on their wells and that some information obtained from owners is not completely accurate. In some cases data which have been obtained by Ministry of Environment from contractors is incorrect in some details.

The base maps used by Ministry of Environment in the Trail-Castlegar area are out of date and not of the best quality so locations on the well location maps are occasionally incorrect. The new mapping provided by B.C. Hydro as far downstream as Oasis is excellent so well locations north of Oasis are probably good. At Oasis there is no

appropriate mapping on which to plot the closely spaced wells so a cadastral map prepared by the Planning Department, Regional District of Kootenay Boundary, has been used. From Oasis to the United States Boundary, wells are plotted on a recent edition of the 1:50,000 scale topographic map (NTS Sheet 82F/4). The small scale causes some problems but most well locations are believed to be quite accurate. Well locations were not surveyed as part of this work.

Wells located at significant distances from the River were not considered in the inventory. One such well is an observation well (WR-16-66) operated by the Ministry of Environment at the Castlegar Golf Course north of Ootischenia. It was established in 1966 and is in a local aquifer formerly used by Ootischenia for domestic supply and for irrigation water by the golf course. The aquifer is an isolated one not connected in any way with the Columbia and Kootenay Rivers. The hydrograph from it shows responses from local recharge and water use.

TABLE A-1 WELL INVENTORY - KEENLEYSIDE DAM - ROBSON AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
1	1									I ♂
	2									I ♂
	3									I
	4									I
	5									I
	6									I
										small community system installed by Hydro (see Wells No. 12 & 16)
	7	Drilled	200	15.54	9.2	Nov. 1961	~9.2	Coarse Gravel		WRS-Kootenay-#3-Z4X10Y34-1 3.6 m of perforated pipe Est. cap. of 6.3 l/sec
	8	Drilled	250	31.09			7.0	Gravel		WRS-Kootenay-#3-Z4X10Y34-2 Open end casing
	9	Drilled	250	37.49	8.5	July 22 1959	9.1	Gravel		WRS-Kootenay-#3-Z4X10Y34-3 1.5 m of perforated casing
	10	Drilled		24.41			~19.5	Sand and Gravel		WRS-Kootenay-#3-Z4X10Y34-4 2.4 m of perforated casing
	11	Drilled	200	30.48			~10.9	Sand, Minor Gravel		WRS-Kootenay-#3-Z4X10Y34-5
	12	Drilled	200	38.10	~9.1	Mar. 22 1965	~ 9.1	Sand and Gravel		WRS-Kootenay-#3-Z4X10Y34-6 Also called Well No. 1 of Balfour Subdivision 1.5 m of 1 mm slot screen from 36.6-38.1 m Max yield of 10.1 l/sec
	13	Drilled	100	18.59	4.9	1954	~10.7	Sand		WRS-Kootenay-#3-Z4X10Y35-2 Screen 1.5 m Est. cap. of 1.5 l/sec
	14	Drilled		19.20	8.8	Jan. 1961	~12.8	Fine Silt (?)		WRS-Kootenay-#3-Z4X10Y35-1 4.6 m of perforated casing Est. cap. of 0.6-1.3 l/sec
	15	Drilled	250	38.10			~9.1	Coarse Gravel		WRS-Kootenay-#3-Z4X10Y35-4 Perforated casing from 33.5-36.6 m
	16	Drilled	250	46.33	~9.9	Mar. 1965	~9.9	Sand and Gravel		WRS-Kootenay-#3-Z4X10Y35-5 Also called Well No. 2 of Balfour Subdivision 6.1 m of 1.3 mm slot screen from 37.1-43.9 m Est. cap. of 53.0 l/sec

TABLE A-2 WELL INVENTORY - ROBSON AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
2										
	1	Drilled	150		18	Nov. 3 1981			100 (pH 8)	I - Submersible pump
	2								120 (pH 8.3)	I
	3									I Hill
	4									I
	5								150 (pH 8)	I
	6									I Gravity feed system from on the hill
	7								120 (pH 8.4)	I
	8									I Private spring Gravity feed system
	9	Drilled	150	22.25	8.5	Jan. 1960	~13.7	Sand and gravel		WRS-Kootenay-#3-Z4X10Y35-3 2.4 m of perforated casing Est. cap. 31.5 l/sec
	10	Drilled	150	15.24	10.06	Apr. 1961	~12.5	Sand and gravel		WRS-Kootenay-#3-Z4X10Y36-1 1.6 m of perforated casing 0.6 l/sec with a D/D of 0.3 m

TABLE A-3 WELL INVENTORY - EAST RASPBERRY AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
3										
	1	Drilled ?	150					Sand and gravel	60 (pH 8)	I
	2	Drilled	150	~18				Sand and gravel	80	I - Submersible pump
	3	Well Point ?	Casing 50 Ø Inside 25 Ø	~18	~6	Nov. 4 1981			40 (pH 7)	I - 0.9 m of screen
	4									I
	5									I } Gravity feed system from hill
	6									I
	7	Dug			6	Nov. 4 1981		Sand and gravel	230 (pH 6.4)	I - 0.9 m dia. concrete casing
	8	Drilled	150	21.3					270 (pH 7.0)	I - Submersible pump
	9	Drilled	150	18.6	~13	Sept. 1965	~13	Sand and gravel	370 (pH 7.5)	I and WRS-Kootenay-#3-Z4X11Y32-5 2 connections - #9 and #16 1.0 mm slot screen at 17.1-18.6 m 1.3 l/sec with D/D of 2.3 m
	10	Drilled	150	22.86	16.5	Nov. 4 1981		Sand and gravel	320 (pH 7.0)	I - Submersible pump screen
	11	Drilled	150	20.73	11.6	Nov. 4 1981		Sand and gravel	380 (pH 7.5)	I - Submersible pump 2 connections - #11 and #23 Est. cap. of 0.8 l/sec
	12	Drilled	200 ?	17.68				Sand and gravel	320 (pH 7.0)	I - Submersible pump
	13									I - On private stream
	14									I - On private stream
	15	Well Point ?	40	~18				Sand and gravel	300 (pH 7.1)	I - Screen
	16	Drilled								I - Same as Well #9
	17	Drilled	150	73.2				Sand and gravel	240	I } 2 connections I } Submersible pump Screen
	18									
	18A									I - On gravity feed system
	19	?							280	I
	20	Drilled	150	21.3					460	I

TABLE A-3 WELL INVENTORY - EAST RASPBERRY AREA (cont'd.)

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
3										
	21									I
	22	Drilled	150	20.7	14.6	Nov. 1981		Sand and gravel	220 (pH 6.7)	I - Submersible pump
	23									I - Same as Well #11
	24	Drilled	150						310 (pH 7.4)	I
	25	Drilled	150	37.49	18.3	Aug. 1966	~33.5	Sand		WRS-Kootenay-#3-Z4X11Y32-3 0.5 mm slot screen at 36.3-37.5 m Est. cap. 1.3 l/sec
	26	Drilled	150	17.37	12.2	Aug. 1966	~13.7	Sand and gravel		WRS-Kootenay-#3-Z4X11Y32-4 1.0 mm slot screen at 16.2-17.4 m Est. cap. 1.3 l/sec
	27	Drilled	150	26.52	17.4	Apr. 1976				WRS-Kootenay-#3-Z4X11Y32-6
	28	Drilled	150	45.72	34.4			Coarse gravel		WRS-Kootenay-#3-Z4X11Y32-7 at 1.3 l/sec with D/D of 7.6 m
	29	Drilled	150	45.72	35.9			Sand and gravel		WRS-Kootenay-#3-Z4X11Y32-8 at 0.6 l/sec with D/D of 7.6 m
	30	Drilled	150	45.72	34.1	Apr. 1976	~39.6	Sand and gravel		WRS-Kootenay-#3-Z4X11Y32-9 at 0.6 l/sec with D/D of 9.1 m 1.0 mm slot screen from 44.5-45.7 m
	31	Drilled	150	50.90	16.8					WRS-Kootenay-#3-Z4X11Y32-10 at 2.3 l/sec with D/D of 15.2 m Open end casing
	32	Drilled	400	44.96	14.8	1960	25.9	Sand and gravel		WRS-Kootenay-#3-Z4X11Y30-1 14.3 m of perforated casing Test pumped at 113.6 l/sec with D/D of 6.1 m Now abandoned Castlegar Prod. Well No. 2
	33	Drilled	200	31.09	13.2	Aug. 1959	25	Sand and gravel		WRS-Kootenay-#3-Z4X11Y30-2 Perforated casing from 25.6-31.1 m Test pumped at 60.6 l/sec with D/D of 2.6 m Now abandoned Castlegar Prod. Well No. 1

TABLE A-3 WELL INVENTORY - EAST RASPBERRY AREA (cont'd.)

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
3	34	Drilled	400	38.40	19.8	July 1970	~27	Sand and gravel		WRS-Kootenay-#3-Z4X11Y30-3 5.1 mm slot screen at 27.4-30.5 m and 36.6-37.8 m Est. cap. 63.1 l/sec Castlegar Prod. Well No. 3 now standby well for North Castlegar
	35	Drilled	150	43.59	18.3	Aug. 1966	~18.3	Coarse sand	(pH 7)	WRS-Kootenay-#3-Z4X11Y32-2 0.8 mm slot screen at 42.4-43.6 m Est. cap. 1.9 l/sec
	36	Drilled	150	20.12	8.5	Feb. 1953	~9.1	Coarse sand		WRS-Kootenay-#3-Z4X11Y32-1 1.5 m of screen Est. cap. 75.7 l/sec

TABLE A-4 WELL INVENTORY - BRI[illegible]NT-OOTISCHENIA AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
4										
	1	Drilled	150	23.16	18.6	Nov. 6 1981		Sand and gravel	410 (pH 7.4)	I - Submersible pump Well has screen
	2	Drilled	150	19.51					500 (pH 7.5)	I - Submersible pump
	3	Drilled	150	17.98				Sand and gravel	320 (pH 7.5) (T = 10° C)	I - Est. cap. of 1.6 l/sec
	4	Drilled	?	?						I - Submersible pump for drinking water
	5	?								I - Neighbor says no well
	6	Drilled	150	21.95	17.7	Nov. 2 1981		Sand and gravel	330 (pH 7.6)	I - Submersible pump 1.2 m of screen Est. cap. 1.2 l/sec
	7	?								I
	8	Drilled	150	19.81	9.1	Nov. 2 1981		Sand and gravel	170 (pH 7.4)	I
	9	Drilled	150	19.81				Sand and gravel		I - Jet pump 2 connections
	10	Drilled	150	18.29				Sand and gravel	160 (pH 7.7)	I
	11	Drilled	?	22.86	19.81	Nov. 2 1981		Sand and gravel	200 (pH 7.0)	I - Jet pump
	12	Drilled	150	10.97				Sand and gravel		I - Submersible pump
	13	Drilled	150	27.43				Sand and gravel	410	I - Submersible pump Serves 2 houses 0.914 m of screen Est. cap. 1.3 l/sec on hill for irrigation
	14	Drilled	200	42.37	21.9	Nov. 6 1981	23.5	Sand	200 (pH 7.5)	I and WRS-Kootenay-#3-Z4X11Y29-3 0.8 mm slot screen at 39.3-42.4 m Pumped at 18.9 l/sec with D/D of 3 m
	15	Drilled	?	?				Sand and gravel	250 (pH 7.5)	I - Submersible pump Est. cap. 3.2 l/sec
	16	Drilled	150	32.92	20.4	Nov. 6 1981		Sand and gravel	140 (pH 7.5)	I - 1.2 m of screen Serves 6 houses

TABLE A-4 WELL INVENTORY - BRILLIANT-OOTISCHENIA AREA (cont'd.)

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
4										
	17	Drilled	250	15.80	9.8	Nov. 1961	10	Sand and gravel		WRS-Kootenay-#3-Z4X11Y20-2 4.3 m of perforated casing Est. cap. of 50.5 l/sec
	18	Drilled	200	34.75	15.8	Aug. 1965	16 m	Sand and gravel		WRS-Kootenay-#3-Z4X11Y20-4 1.5 mm slot screen from 28.6-34.7 m Pumped at 22.7 l/sec with D/D of 0.48 m
	19	Drilled	300	52.43	12.2	Oct. 1974	19 m	Gravel		WRS-Kootenay-#3-Z4X11Y20-5 0.6 mm slot screen from 37.8-43.9 m Pumped at 99.1 l/sec with D/D of 0.3 m
	20	Drilled	400	47.55	12.4	May 31 1978	14.6	Gravel	150	WRS-Kootenay-#3-Z4X11Y20-6 6.4 mm slot screen from 27.3-43.0 m Pumped at 139.0 l/sec with D/D of 0.55 m

TABLE A-5 WELL INVENTORY - KINNAIRD-OOTISCHENIA AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY (microsiemens)	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL		
5										
	1	Drilled	150	60.96	38.4	Apr. 1960	~37.5	Coarse gravel		WRS-Kootenay-#3-Z4X11Y20-1 6.096 m of perforated casing Est. cap. of 18.9 l/sec
	2	Drilled	400	118.87	64.3	Apr. 1965	~64	Sand and gravel		WRS-Kootenay-#3-Z4X11Y17-3 South Castlegar Well No. 3 1.0 mm slot screen from 105.5-114.0 m Well cap. of 47.3 l/sec Now abandoned
	3	Drilled	400	103.63	61.6	Feb. 1965	~62	Sand and gravel		WRS-Kootenay-#3-Z4X11Y8-1 South Castlegar Well No. 1 1.0 mm slot screen Well cap. 13.2 l/sec Now abandoned
	4	Drilled	400	108.97	58.8	May 1965	~59	Sand and gravel		WRS-Kootenay-#3-Z4X11Y8-2 South Castlegar Well No. 2 2.5 mm slot screen Well cap. 31.6 l/sec Now abandoned

TABLE A-6 WELL INVENTORY - OOTISCHENIA AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
6										
	1	?	?	?						I - No info. available Probably on golf course system
	2									I - On Irrigation District system from golf course. Other wells on Columbia Road also on golf course system.
	3	Drilled	150 ?	30.48	?				340 (pH 7.4)	I - 4 connections (2 domestic, restaurant and bar) Submersible pump
	4	Drilled	150	50.3						I - Well capped and not in use
	5	Drilled	150	19.51	12.8	Feb. 1977	~17.4	Sand	430 (pH 7.6)	I - 2 connections Submersible pump Est. cap. 0.4 l/sec
	6	Drilled	400	76.20	7.0	Sept. 1970	~ 7.0	Sand and gravel		WRS-Kootenay-#3-Z4X11Y8-3 Castlegar South System Well No. 4 0.76 mm slot screen from 67.0-76.2 m Est. cap. of 44 l/sec Retained as stand-by well
	7	Drilled	150	19.20	11.6	May 1964	~11.6	Sand		WRS-Kootenay-#3-Z4X11Y5-2 Pumped at 0.2 l/sec for 2 hrs. with D/D of 3.6 m
	8	Drilled	150	73.15	59.1	Nov. 1969	~59	Sand		WRS-Kootenay-#3-Z4X11Y9-4 Ootischenia Waterworks District Well No. 1 0.5 mm slot screen 1.0 mm slot screen } 70.1-73.1 m Pumped at 3.2 l/sec with D/D of 4.6 m
	9	Drilled	200	73.15	57.9	July 1981	~58	Sand and gravel		Ootischenia Waterworks District Well No. 2 1.5 mm slot screen 2.0 mm slot screen } 65.8-69.2 m Est. cap. of 14.4 l/sec
	10	Drilled	150	15.24	13.4	Sept. 1972	~13	Sand		WRS-Kootenay-#3-Z4X11Y4-1 0.5 mm slot screen 1.2 m long

TABLE A-7 WELL INVENTORY - BLUEBERRY CREEK AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
7										
	1	Drilled	150	~73	~58			Sand		I - Screen
	2	Drilled	150	~60	~21			Fine sand		I - No screen
	3	Drilled	150	11.28	8.2	Oct. 1962			(pH 7.5)	WRS-Kootenay-#2-Z3X11Y29-1 Perforated casing
	4	Drilled	150	56.99	33.8	Aug. 1965	~45	Sand and gravel		WRS-Kootenay-#2-Z3X11Y31-1 Perforated casing from 45.5-48.4 m Est. cap. 1.9 l/sec

TABLE A-8 WELL INVENTORY - POUPORE-GENELLE AREA

8										
	1	Drilled	150	20.73	12.8	Nov. 6 1981	~13	Sand and gravel	412 (pH 13)	I - 0.76 mm slot screen 1.2 m long Est. cap. of 2.2 l/sec
	2	Drilled	150	?	?			Sand and gravel		I - Est. cap. of 2.2 l/sec
	3	Drilled	150	28.04	9.1	Nov. 6 1981		Sand and gravel		I - Screen 1.2 m long Est. cap. 1.9 l/sec
	4	Drilled	150	58.52	46 ?	Nov. 9 1981		Sand and gravel		I - Not in service, capped
	5	Drilled	?	53.64	1.2 m above river	Oct. 9 1981		Sand		I - Used as an auxiliary supply. 0.5 mm slot screen 4.6 m each 0.6 mm slot screen Est. cap. of 15.8 l/sec Genelle gets water from China Creek
	6	Drilled	250	46.94	24 +	Oct. 9 1981		Sand and gravel	200	I - Well is just beyond perimeter of mapped area Screen 1.8 m long Est. cap. of 0.6 l/sec
	7	Drilled	150	28.04	9.9	May 27 1962	~10	Sand	(pH 7.5)	WRS-Kootenay-#2-Z3X11Y18-1 11.3 m of perforated casing Est. cap. of 0.6-1.2 l/sec Pumped at 2.3 l/sec with D/D of 1.6 m

TABLE A-9 WELL INVENTORY - SULLIVAN CREEK AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY (microsiemens)	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL		
9	1	Drilled	150	26.52	11.3	Mar. 1960	18 ?	Sand		WRS-Kootenay-#2-Z3X10Y2-1 11.8 m of perforated casing Est. cap. of 19 l/sec

TABLE A-10 WELL INVENTORY - BIRCHBANK-RIVERVALE AREA (OASIS - SEE MAP 11)

10	1								40	I - Pumped system from Murphy Creek supplies golf course
	2								50	I - Pumped system from Hanna Creek supplies Rivervale

TABLE A-11 WELL INVENTORY - OASIS AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
11										
	1	Spring						?		I, Same system - Uses spring for domestic water
	2	Sand point						Sand	120	I - Sand point for irrigation
	3	Dug	1.2 m sq.	12.19	5	Nov. 12 1981		Sand and gravel		I - Uses spring for domestic water
	4	Dug	1.2 m sq.	6.1	6	Nov. 12 1981		Sand and gravel	100 T=10°C	I
	5	Drilled	150	131.06	Non-flowing artesian	Nov. 12 1981		Sand and gravel	240 (pH 8.2)	I - Submersible pump Well used in summer Est. cap. of 1.2 l/sec
	6	Sand points							440	I - 2 sand points in basement
	7	Drilled	150	5.79	3.0	Nov. 10 1981		Sand	220 (pH 5.9)	I - Submersible pump 0.76 mm slot screen from 4.26-5.79 m Est. cap. of 0.5 l/sec
	8	Dug	1.2 m sq.	3.05						I - Not in service Shares well with #7
	9	Drilled	150	91.44	?			Rock	300	I - Submersible pump Est. cap. of 0.19-0.22 l/sec
	10	Drilled	150	106.68	0 to 6.1	Nov. 10 1981		Rock	360	I - Submersible pump Est. cap. of 0.16 l/sec
	11	Dug	750	6.10	1.2 to 5.2	Nov. 1981		Sand and gravel	660	I - Est. cap. of 0.02 l/sec Concrete rings
	12	Drilled	150	106.68	<27	Nov. 11 1981		Rock	360	I - Submersible pump Est. cap. of 0.3 l/sec
	13	Drilled	200	13.7	~1.5	May 1982		Sand, minor gravel	240	I - Oasis Waterworks District Well No. 2 125 mm slot screen 4.6 m long Cap. of 0.5 l/sec
	14	Drilled	150	22.6	~0.6	May 1982		Sand, minor gravel		I - Oasis Waterworks District Well No. 3 125 mm slot screen 4.9 m long Cap. of 1.1 l/sec

TABLE A-11 WELL INVENTORY - OASIS AREA (cont'd.)

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY (microsiemens)	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL		
11										
	15	Drilled	200	19.8	~3	May 1982		Fine sand		I - WRS-Kootenay-#2-Z2X10Y22-1 Oasis Waterworks District Well No. 1 0.25 mm slot screen from 17.1-19.8 m Well is not in service Est. cap. of 0.8 l/sec Hole in casing 2.1 m below ground Well can be rehabilitated by patching casing
	16	Dug	1.8 m	3.05					360	I - Submersible pump
	17	Drilled	150	7.62	3.0	Nov. 12 1981		Sand and gravel	460	I - Submersible pump 2 connections Screen 1.2 m long Est. cap. of 1.6 l/sec
	18	Drilled	150	10.36	4.6	Nov. 12 1981		Sand and gravel	500	I - Submersible pump Screen 1.2 m long Est. cap. of 0.5 l/sec
	19	Sand point		5.49					140	I - 2 connections Est. cap. of 0.2 l/sec
	20A	Dug	1.2 m sq.	3.05	2.1 to 3.0	Nov. 12 1981		Gravel	500	I - A for domestic use
	20B	Dug	1.2 m sq.	2.44						B for irrigation
	21	Dug	1.8 x 2.4 m	3.05	1.8	Nov. 12 1981			500	I - Est. cap. of 0.06 l/sec

TABLE A-12 WELL INVENTORY - TRAIL-MONTROSE AREA

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
12 portion of NTS 82 F/4	1	Drilled	300 and 250	64.31	42.7	Mar. 1962	47	Sand and gravel	371 (pH 7.8)	I and WRS-Kootenay-#30-Z1X11Y33-1 6.1 m of perforated casing Pumped at 15 l/sec with D/D of 12.2 m (June 1981) Supplies system with 90 connections; prone to clogging New well under construction Green Gables Waterworks
	2	Drilled	150	70.10	6.1 to 9.1	Apr. 29 1982		Rock	390	I and WRS-Kootenay-#30-Z1X11Y34-1 Est. cap. of 0.5 l/sec
	3	Drilled	150	30.48				Rock	290	I - 2 domestic connections
	4	Drilled	200	39.94	~7.6	July 1966	~7.6	Silty sand and gravel		I and WRS-Kootenay-#1-Z2X11Y4-1 1.0 mm slot screen from 36.9-39.9 m Pumped at 9.5 l/sec with D/D of 14.6 m
	5	Drilled	150	20.73				Sand and gravel		I - Screen 1.2 m long Est. cap. of 0.9 l/sec
	6	Drilled	150	19.51	~11.3	Apr. 29 1982			260	I - Screen from 18.3-19.5 m Est. cap. of 0.8 l/sec
	7	Drilled	150							I - 2 wells; one for domestic one for sprinkling
	8	Drilled	150	21.34				Sand and gravel		I and WRS-Kootenay-#1-Z2X11Y4-5 0.76 mm slot screen from 20.1-21.3 m Est. cap. of 3.2 l/sec
	9									♂ WRS-Kootenay-#1-Z2X10Y15-1
	10									♂ WRS-Kootenay-#1-Z2X10Y15-2
	11	Drilled	?	97.23	11.0	Jan. 1965	~11	Sand, minor gravel		WRS-Kootenay-#1-Z2X10Y14-1 Trail Production Well No. 1
	12	Drilled	?	100.43	12.2	Apr. 1965	~12	Sand, minor gravel		WRS-Kootenay-#1-Z2X10Y14-2 Trail Production Well No. 2
	13	Drilled	400	110.64	9.5	Oct. 1971	~9.5	Sand, minor gravel	(pH 7.9)	WRS-Kootenay-#1-Z2X10Y1-1 Trail Production Well No. 3 0.76 mm slot screen from 93.6-110.7 m Capacity rated at 26 l/sec at 25% safety factor after construction

TABLE A-12 WELL INVENTORY - TRAIL-MONTROSE AREA (cont'd.)

MAP NO.	WELL NO.	DESCRIPTION OF WELL					PRINCIPAL AQUIFER		CONDUCTIVITY	REMARKS
		TYPE	CASING DIAM. (mm)	DEPTH (m)	STATIC LEVEL (m)	STATIC LEVEL DATE	DEPTH TO TOP (m)	MATERIAL	(microsiemens)	
12										
	14	Drilled	500	87.8	14		~20	Sand and gravel	T.D.S.=112 mg/l	Trail Production Well No. 4 350 mm pipe size screen assembly from 64.0-87.8 m Capacity is very high
	15									WRS-Kootenay-#1-Z2X11Y4-6
	16	Drilled	150	25.91	14.8	Jan. 1960	~14.8	Fine sand		WRS-Kootenay-#1-Z2X11Y4-2 Screen 3.0 m long Est. cap. of 3.2 l/sec
	17	Drilled	150	155.45	?					WRS-Kootenay-#30-Z1X11Y33-3
	18	Drilled	400	38.71	9.1	June 1961	~9	Sand and gravel		WRS-Kootenay-#30-Z1X11Y27-2 Village of Montrose Well No. 1 9.1 m of perforated casing Well cap. of 48.4 l/sec
	19	Drilled	400	48.20	4.9	Dec. 1981	~5	Sand and gravel		Village of Montrose Well No. 2 Screen 10.9 m long Well cap. of 28.4 l/sec
	20	Drilled	200	37.49	8.9	Dec. 1968	~9	Sand		WRS-Kootenay-#30-Z1X11Y27-1 0.2 mm slot screen from 32.6-36.3 m Pumped at 2.5 l/sec with D/D of 15.2 m
	21	Drilled	150	58.52						Est. cap. of 8.2 l/sec
	22	Drilled	250	94.49	27.1	Feb. 1978		Sand		Gravel pack construction 125 mm slot screen
	23	Drilled	175	21.34	15.2	Nov. 1964	~15	Sand	(pH 7.5)	WRS-Kootenay-#1-Z2X11Y4-3 Perforated casing

APPENDIX B

PUMPING TESTS AT OASIS

APPENDIX B

PUMPING TESTS AT OASIS

Short duration pumping tests were carried out on wells at Oasis where the owners gave permission and wished the testing to be done. Because of concerns by residents in the Oasis area that dam construction would have an adverse effect on their wells, the tests were carried out in order that performance of individual wells (prior to dam construction activity) would be known. Following the pumping tests carried out in May 1982, tests of additional wells were requested by the Oasis Action Committee. These tests will be carried out before dam construction.

The pumping tests at Oasis, except the test of Mr. Lamb's well, were carried out using the installed pumps. Water was discharged using garden hoses onto lawns and gardens far enough from the wells to prevent recirculation. Flows were measured by timing the filling of a 22 litre (5 i gal) container. The water level in the pumped well was measured by an electric water level indicator. In the case of two of the deep rock wells, it was not possible to follow the water level all the way down, so the final drawdown is not known. However, enough observations of water levels were taken so that a comparison can be made with a similar test some time in the future.

The water levels recorded at the start of the test may not be true static levels because the wells had been in use prior to the tests, and the water levels may not have returned to the true static level. The tests were also carried out at a time of year when groundwater levels are quite high. The seasonal fluctuation is unknown but it is likely to be fairly large at Oasis because of the topographic position and dry climate.

The objective of the tests is to measure well performance: that is, to measure drawdown at a known pumping rate at a known time after pumping started. In spite of the fact that most rock wells do not conform to the model on which pumping test analyses are based, the performance (measured as outlined above) will remain approximately constant.

In May 1982, pumping tests of nine wells (including two wells owned by the Oasis Waterworks District) were carried out. The results of the pumping tests are recorded in Table B-1. The well inventory located twenty-two wells in the Oasis area; details of the well inventory are given in Table A-11. The location of the Oasis area wells are shown on Figure 2-11.

Table B-1. Results of Pumping Tests at Oasis

Well Owner	Distance to Water at Start (m)	Duration of Test (min)	Pumping Rate (l/sec)	Drawdown at End of Test (m)	Type of Aquifer	Remarks
Oasis Waterworks						
Well 2	approx. 1.8	approx. 40	.760	7.2	sand	tested after redevelopment
Well 3	0.92	380	1.260	10.88	sand	tested after redevelopment
Conn	1.28	85	.567	2.56	sand	domestic, 2 houses
Doig	1.37	63	.469	3.61	sand	domestic
Laithwaite	13.40	121	.516	39.4	rock	domestic
Makortoff	0.57	190	.910	.418	sand	domestic and irrigation
Lamb	1.83	59	3.240	2.9	sand	dug well, lawn and garden water
Jordany	5.92	120	.484	est. 60	rock	@ 45 min, drawdown 43.08 m - domestic
Kushner	2.70	83	.505	more than 57	rock	@ 53 min, drawdown 47.70 m - domestic

APPENDIX C

WATER QUALITY INFORMATION

APPENDIX C

WATER QUALITY INFORMATION

Appendix C contains information on water quality relevant to two aspects of the study:

1. Impacts on the quality of water from wells supplying domestic water in the Oasis area caused by construction of the proposed dam.

2. Impacts on the quality of water from wells caused by sediment in the Columbia River downstream of the dam site during construction.

In May 1982, during pump testing at Oasis, samples of water were taken from a typical rock well (Laithwaite) and from the wells of the Oasis Waterworks District, typical of wells drawing water from the sandy terrace sediments. These samples were analyzed by Can test Ltd. in Vancouver for the constituents which are customarily checked to determine the suitability of water for domestic use.

At the request of the Oasis Action Committee, additional water analyses were carried out on water from individual domestic wells. The samples were collected in January 1983 by running the cold water faucet. The analyses were carried out by Analytical Service Laboratories Ltd. in Vancouver.

These analyses (given in Table C-3) will provide background information prior to dam construction in the event that claims arise in regard to water quality changes from construction activity. The groundwater from the Oasis Waterworks District Wells is a calcium-magnesium/sulphate-bicarbonate type of water; the groundwater from the Laithwaite Well (April 1982 sample) is a calcium-magnesium/bicarbonate-sulphate type of water. The groundwater types show clearly that both

wells obtain water from a groundwater flow system moving from the side of the Columbia River Valley toward the River (See Figure 3-2 A. Hydro-geological Cross-section B-B').

A number of shallow wells that obtain water from sandy terrace sediments at Oasis show elevated levels of nitrate. In addition, a number of the wells show elevated levels of zinc: in particular, water from W.A. Jordany's rock well initially showed zinc considerably in excess of the maximum acceptable Canadian Drinking Water Guideline of 5 mg/l (established by Health and Welfare Canada in 1978). The Jordany Well was resampled from an outside faucet after about twenty minutes of pumping. The recheck showed a zinc concentration of 5.3 mg/l. It is most likely that the zinc in the groundwater at Oasis is from natural sources.

The only places where there is any possibility of Columbia River water getting into wells are at two wells of the City of Trail and two wells of the Village of Montrose. These are wells close to the River bank. As discussed previously, water movement in the sediments along the Columbia River is toward the River. Four analyses of water from the Trail wells are included along with two analyses from the Columbia River, one at high water and one at low water. These analyses may be compared; they show clearly that the well water is not similar to that from the River. The locations of the Trail wells are shown on Figure 2-12 and some details about the wells are given in Table A-12.

Table C-1. Groundwater Quality - Trail Wells

CONSTITUENT	SUNNINGDALE PRODUCTION WELL No. 1	SUNNINGDALE PRODUCTION WELL No. 2	MCLEAN STREET PRODUCTION WELL No. 3	BEAR CREEK PRODUCTION WELL No. 4
Date sample was taken	Jan. 20, 1965	Apr. 24, 1965	Oct., 1971	Feb. 1, 1979
Turbidity (JTU)	1.5-2	1.8	2.9	-
pH			7.90	7.22
Colour (CU)	5	5	3.7	-
Total Hardness (mg/l)	113-122	190	157.5	85
Dissolved Anions (mg/l)				
Total Alkalinity	86.4-92.5	119	-	60
Bicarbonate Alkalinity			155	73
Chlorides			1.0	2
Sulphates	27.5-55	49.0	34.1	25
Phosphates			L 0.1	-
Nitrates + nitrite (as N)			0.6	L 0.2
Dissolved Cations (mg/l)				
Silica	-	12.4	8.2	-
Iron	0.01-0.07	0.49	L 0.05	-
Aluminum			L 0.05	-
Calcium	32.5-35.0	56.0	48.4	26
Magnesium	7.5-8.0	12.0	8.9	5
Sodium			2.9	2
Potassium			2.6	
Manganese			0.10	-
Copper			0.01	-
Lead			L 0.01	-
Zinc			L 0.01	-
Fluoride (mg/l)	0.2	0.4	-	L 0.1
Total Iron (mg/l)			0.05	0.05
Total Silica (mg/l)			8.4	-

cont'd ... C-4

Table C-1. Groundwater Quality - Trail Wells (cont'd.)

CONSTITUENT	SUNNINGDALE PRODUCTION WELL No. 1	SUNNINGDALE PRODUCTION WELL No. 2	MCLEAN STREET PRODUCTION WELL No. 3	BEAR CREEK PRODUCTION WELL No. 4
Solids (mg/l)				
Total Dissolved Solids	190	219	264	112
Volatile Solids	14	-	78	31
Fixed Solids	108	-	186	-
Suspended Matter	-	-	0.7	-
Specific Conductance (micromhos/cm)	256-265	300		

L = less than

Sources of data

Production Well No. 1 - Trail Waterworks Survey Appendix B

Production Well No. 2 - as above

Production Well No. 3 - Chemical Analysis of Water Samples - File No. 2171 A
Cantest Ltd., Vancouver, B. C.

Production Well No. 4 - Water Analysis Report No. 339-43
Western Industrial Laboratories Limited, Edmonton, Alberta

Table C-2. Quality of Columbia River Water

Date sample was taken	Oct. 1, 1969	June 1970
Turbidity (JTU)	0.9	1.0
pH	7.9	8.1
Colour (CU)	5	5
Total Hardness (mg/l)	62.1	69.0
Dissolved Anions (mg/l)		
Total Alkalinity as $CaCO_3$	54	55
Bicarbonate Alkalinity	65	68
Chlorides	0.6	0.7
Sulphates	10.3	13.6
Phosphates	-	0.029
Nitrates + nitrite (as N)	0.339	0.068
Dissolved Cations (mg/l)		
Silica	2.6	4.8
Iron	-	-
Aluminum	-	-
Calcium	20.5	21.0
Magnesium	2.6	4.0
Sodium	1.3	1.8
Potassium	0.6	0.6
Manganese	-	L 0.01
Copper	L 0.01	L 0.01
Lead	-	L 0.01
Zinc	0.02	0.03
Fluoride (mg/l)	L 0.01	0.02
Total Iron (mg/l)	-	-
Total Silica (mg/l)	-	-

cont'd ... C - 6

Table C-2. Quality of Columbia River Water (cont'd.)

Solids (mg/l)		
Total Dissolved Solids	71	80
Volatile Solids	-	-
Fixed Solids	-	-
Suspended Matter	-	-
Specific conductance (micromhos/cm)	135	14

L = less than

Source of data

Environment Canada - Water Quality Data
British Columbia
1961 - 1971

Columbia River - at Stoney Creek Pumphouse, above Trail, B.C. Station No. 00BC08NE0004

Table C-3. Groundwater Quality at Oasis

SAMPLE IDENTIFICATION		OASIS WATERWORKS DISTRICT WELL	LAITHWAITE WELL		ASHTON WELL	BROCKE WELL	CONN WELL
Date sample was taken		* June 17, 1982	+ April 1982	# Jan. 1983	# Jan. 1983	# Jan. 1983	# Jan. 1983
PHYSICAL TESTS							
pH		6.95	8.25	7.34	6.90	6.50	5.95
Conductivity (micromhos/cm)		196.	396.	293.	310.	395.	140.
Colour (Pt-Co scale) (CU)		L 5.	L 5.				
Turbidity (JTU)		0.16	0.22	0.11	0.30	0.05	0.25
Hardness (mg/l)	CaCO3	76.0	172.	180.	362.	462.	164.
SOLIDS (mg/l)							
Total Suspended		L 1.0	1.5				
Total Dissolved		136.	300.	272.	179.	216.	64.2
DISSOLVED ANIONS (mg/l)							
Alkalinity: Bicarbonate	HCO3	36.6	154.	126.	124.	76.	20.
Alkalinity: Carbonate	CO3	Nil	Nil				
Alkalinity: Hydroxide	OH	Nil	Nil				
Chlorides	Cl	0.98	L 0.5				
Sulphates	SO4	51.5	62.5				
Nitrates and Nitrites	N	0.30	0.96	0.73	1.10	3.93	0.87
Ortho Phosphates	P	L 0.010	L 0.010	0.032	0.052	0.064	0.016
Fluorides	F	0.080	0.38	0.34	0.11	0.30	0.17
DISSOLVED METALS (mg/l)							
Barium	Ba			0.004	0.076	0.077	0.040
Boron	B			0.005	0.012	0.043	0.009
Cadmium	Cd	L 0.001	L 0.001				
Calcium	Ca	22.9	55.6	58.7	55.7	66.5	21.4
Chromium	Cr			L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	L 0.001	L 0.001	0.010	L 0.005	0.170	0.065
Iron	Fe	L 0.030	L 0.030	L 0.020	L 0.020	L 0.020	L 0.020
Lead	Pb	L 0.001	L 0.001	L 0.020	L 0.020	L 0.020	L 0.020
Magnesium	Mg	4.36	7.66	8.09	9.76	12.2	2.62
Manganese	Mn	L 0.003	L 0.003	L 0.010	L 0.010	L 0.010	0.014
Potassium	K	2.14	2.86	3.75	4.88	6.76	3.90
Silica	SiO2	13.9	9.95				
Sodium	Na	2.94	4.45	5.83	9.89	21.8	6.01
Zinc	Zn	L 0.015	0.27	0.75	0.030	0.22	0.62
TOTAL METALS (mg/l)							
Iron	Fe	L 0.030	0.034	L 0.020	L 0.020	L 0.020	L 0.020
Manganese	Mn	L 0.003	L 0.003				

mg/l = milligrams per litre
L = less than = not detected

Sources of Data: * Cantest Ltd. File 6789E. July 8, 1982. + Cantest Ltd. File 6732E. July 9, 1982. # Analytical Service Laboratories Ltd. File 128A. Jan. 31, 1983.

Table C-3. Groundwater Quality at Oasis (cont'd)

SAMPLE IDENTIFICATION		DOIG WELL	JORDANY WELL	KASSIAN WELL	KUCHNER WELL	LAMB SPRING	LANGILLE WELL
Date sample was taken		Jan. 1983	Jan. 1983	Jan. 1983	Jan. 1983	Jan. 1983	Jan. 1983
PHYSICAL TESTS							
pH		6.52	6.58	6.61	6.90	5.92	5.90
Conductivity (micromhos/sm)		24.5	150.	255.	245.	103.	103.
Turbidity (JTU)		3.0	1.2	1.6	1.8	0.01	0.61
Hardness (mg/l)	CaCO3	143.	66.2	151.	138.	46.2	43.6
SOLIDS (mg/l)							
Total Dissolved		250.	162.	276.	234.	126.	132.
DISSOLVED ANIONS (mg/l)							
Alkalinity: Bicarbonate	HCO3	68.	50.	78.	86.	12.	12.
Nitrates and Nitrites	N	0.60	0.20	0.070	1.80	0.52	0.11
Ortho Phosphates	p	0.012	0.020	0.028	0.012	0.032	0.024
Fluorides	F	0.08	0.35	0.09	0.20	0.40	0.62
DISSOLVED METALS (mg/l)							
Barium	Ba	0.048	0.024	0.053	0.007	0.048	0.060
Boron	B	0.009	0.005	0.007	0.044	0.007	0.005
Calcium	Ca	45.2	22.5	45.1	47.8	15.7	15.1
Chromium	Cr	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.006	L 0.005	0.005	0.016	0.005	0.005
Iron	Fe	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020
Lead	Pb	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020
Magnesium	Mg	7.41	2.44	9.27	4.62	1.71	1.43
Manganese	Mn	0.010	0.050	0.020	0.010	0.013	L 0.010
Potassium	K	4.08	2.92	4.31	3.09	3.75	2.39
Sodium	Na	7.14	2.82	4.95	7.26	2.78	2.82
Zinc	Zn	0.013	16.0*	0.033	0.87	1.41	1.43
TOTAL METALS (mg/l)							
Iron	Fe	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020	L 0.020

mg/l = milligrams per litre
L = less than = not detected
* Well resampled after pumping for twenty minutes; recheck gave zinc of 5.3 mg/l.

Source of Data: Analytical Service Laboratories Ltd. File 128A. Jan. 31, 1983.

Table C-3. Groundwater Quality at Oasis (cont'd)

SAMPLE IDENTIFICATION		MAKORTOFF WELL	WILSON WELL
Date sample was taken		Jan. 1983	Jan. 1983
PHYSICAL TESTS			
pH		6.65	7.80
Conductivity (micromhos/cm)		290.	215.
Turbidity (JTU)		0.88	0.07
Hardness (mg/l)	CaCO3	176.	113.
SOLIDS (mg/l)			
Total Dissolved		344.	234.
DISSOLVED ANIONS (mg/l)			
Alkalinity: Bicarbonate	HCO3	82.	94.
Nitrates and Nitrites	N	1.11	L 0.002
Ortho Phosphates	P	0.024	L 0.010
Fluorides	F	0.10	1.50
DISSOLVED METALS (mg/l)			
Barium	Ba	0.059	0.002
Boron	B	0.014	0.017
Calcium	Ca	54.7	39.0
Chromium	Cr	L 0.005	L 0.005
Copper	Cu	0.28	0.012
Iron	Fe	L 0.020	L 0.020
Lead	Pb	L 0.020	L 0.020
Magnesium	Mg	9.52	53.8
Manganese	Mn	L 0.010	0.029
Potassium	K	4.17	0.66
Sodium	Na	8.02	18.8
Zinc	Zn	0.027	0.14
TOTAL METALS (mg/l)			
Iron	Fe	L 0.020	L 0.020

mg/l = milligrams per litre
L - less than = not detected

Source of Data: Analytical Service Laboratories Ltd. File 128A. Jan. 31, 1983.